GEOGRAPHICAL AND TEMPORAL DISTRIBUTION OF ATMOSPHERIC MUTAGENS IN CALIFORNIA

Final Report
CALIFORNIA AIR RESOURCES BOARD
CONTRACT NUMBER A9-077-31

Principal Investigator
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Abstract

The Statewide Air Pollution Research Center continues to assess the mutagenic potency, as determined by the Ames Salmonella/mammalian-microsome assay, of suspended particulate matter in the South Coast Air Basin (SCAB). This program was designed to reveal factors influencing the diurnal variation and geographical distribution of the mutagenicity associated with airborne particles and to establish current "baseline" levels of this mutagenicity for future reference. The current year of this program involves identification of the chemical species responsible for this observed mutagenicity.

Most studies to date have determined the mutagenicity for sampling periods of 24 hours or more. Unfortunately, a collection period of this length averages any mutagenicity peaks which might have occurred. Furthermore, such data may not have sufficient time-resolution to permit assessments of the nature of the mutagen sources (i.e., mobile vs. stationary emissions or primary vs. secondary pollutants). Therefore, investigations were conducted on diurnal variations in the mutagenicity of ambient particles collected simultaneously at several sites across the SCAB. These collections were made every twelve hours for a 72-hour period in winter 1980 and every three hours for a 24-hour period, on two late summer days in 1980 and an early spring day in 1981.

The following conclusions can be drawn from this program:

- Levels of particulate mutagenicity are highly variable, ranging over nearly two orders of magnitude during the sampling periods used in this work.

- Both direct-acting and activatable mutagens are present in the organic extracts from suspended particles collected in the SCAB.

- Average mutagen density is generally higher during the nighttime hours than during the day.

- The diurnal variation exhibited by particulate mutagenicity is similar to that expected of a primary pollutant, with the levels responding to emission rates and atmospheric mixing heights. Significant positive correlations are observed between the mutagen parameters and NO, NO_2, and CO levels, while secondary pollutants such as ozone and peroxyacetyl nitrate correlate negatively.

- Nitroarenes may contribute substantially to the mutagenicity of ambient particulate organic matter in the SCAB.

- No clear evidence for or against atmospheric transformations which may affect particulate mutagenicity is apparent from our data.

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I. EXECUTIVE SUMMARY

This document reports the results of work performed at the Statewide Air Pollution Research Center under California Air Resources Board Contract A9-077-31, "Geographical and Temporal Distribution of Atmospheric Mutagens in California," and carried out during the period from December 10, 1979 to June 30, 1981. This investigation concerns the potential health hazard confronting urban dwellers in California's South Coast Air Basin (SCAB) from the inhalation and subsequent deposition of combustion-related particulate organic matter (POM) present in the polluted atmosphere.

Extracts of airborne particulate organic matter (POM) collected in urban areas throughout the world have been known for several decades to be carcinogenic in experimental animals (Leiter et al. 1942, National Academy of Sciences 1972, 1981, Santodonato et al. 1979). Furthermore, these extracts are directly mutagenic in the Ames Salmonella assay (Pitts et al., 1977a,b, Talcott and Wei 1977, Tokiwa et al. 1977, Chrisp and Fisher 1980, Hoffmann et al., 1980) with the activity concentrated in particles < 1 μm in diameter [i.e., in the respirable size range (Pitts et al. 1978a,b, Pitts 1979, Talcott and Harger 1980].

It is important to determine the sources of this activity, as well as the ambient levels to which urban and suburban populations may be exposed. Most studies to date have determined the mutagenicity for sampling periods of 24 hours or more. Unfortunately, a collection period of this length averages any mutagenicity peaks which might have occurred. Furthermore, such data may not have sufficient time-resolution to permit assessments of the nature of the mutagen sources (i.e., mobile vs. stationary emissions or primary vs. secondary pollutants). Therefore, investigations were conducted on diurnal variations in the mutagenicity of ambient particles collected simultaneously at several sites in the SCAB. These collections were made every twelve hours for a 72-hour period during winter 1980 and every three hours for a 24-hour period, on two late summer days in 1980 and an early spring day in 1981.

Research performed during the first contract period of this continuing investigation has included adaptation of the Ames test to quantitative measurement of ambient particulate mutagenicity, development and

validation of collection, extraction and sample handling methodology for use in such assays, examination of the effects of various filter types on the measured mutagenic activity of the collected sample, and quantitative measurement of the average airborne particulate mutagenicity (day vs. night) at eight sites in the SCAB over a period of three days in July 1979. The results of these studies, detailed in our earlier report (Pitts et al., 1980), demonstrated a large variability in the intensity of particulate mutagenicity impacting the populations of the SCAB, both in terms of geographical location and time of day. Concurrent with the mutagenicity assays conducted during these earlier experiments, data on air mass transport and air quality were compiled in an attempt to observe correlations among these more easily measured parameters and mutagenicity associated with ambient POM. However, limitations in the size of the data set and in the time resolution of the mutagenicity measurements limited the level of confidence which could be placed in the observed trends.

During the period covered by this report, we have greatly expanded our data set of POM mutagenicity and air quality measurements, and have improved the time resolution of the POM mutagenicity measurement by decreasing sampling increments to only three hours. The following paragraphs outline the results of the past year's research into this important aspect of urban air pollution; details of the work carried out under this program are contained in Sections II through IV.

A. Analytical Protocols for POM Mutagenicity Measurements

POM samples were collected on tared Pallflex T60A20 Teflon-impregnated glass fiber filters by conventional high volume filtration. The samplers were calibrated to ensure accurate flow rates, and the filters were pre-cleaned by Soxhlet extraction with CH_2Cl_2 and CH_3OH to provide low organic background levels. After collection, each filter was reweighed to determine particulate loading and then stored at $-20^{\circ}C$ in the dark prior to extraction. As soon as possible after collection, each filter or group of filters was repeatedly extracted by ultrasonic agitation in a mixture (1:1:1) of dichloromethane, methanol and toluene. The combined extracts were filtered, reduced in volume under vacuum (> 20 Torr) and blown to dryness to constant (± 1%) weight with a stream of dry

nitrogen at 35-40°C. The samples were then redissolved in dimethylsulfoxide and submitted to our microbiology laboratory for Ames assay. They were stored at -70°C until actual testing could be performed.

The mutagenicity assays were conducted using the protocol recommended by Ames (Ames et al. 1975) but incorporating refinements developed in these laboratories (Belser et al. 1981) which improve the precision of the test. Preliminary screens of the samples were performed to determine the proper dosage levels, the most responsive tester strain, and the optimum S9 (mammalian metabolic enzyme extract) concentration to be used for observation of activatable mutagenicity. The quantitative assay of each sample set was performed during a single day whenever possible, using triplicate plates and a parallel assay of standard mutagens [benzo(a)-pyrene (BaP), 2-nitrofluorene (2-NF), 2-aminoanthracene (2-AA) and quercetin] to provide verification of normal strain response. Revertant colonies on each sample plate were entered into a computer together with the other relevant sample parameters, and the test data was automatically reduced and printed out in final form. The final mutagenicity data were tabulated as mutagen density (revertants per cubic meter of sampled air), a measure of the impacted populations' exposure to the substances detected by the Ames test, and as mutagen loading (revertants per milligram particulate), a measure of the concentration of substances active in the Ames test on a mass basis which may be useful in distinguishing different particulate mutagen sources and in establishing the effects of atmospheric reactivity on the POM.

Concurrent with each sample collection and analysis, air quality parameters (NO, NO_2, SO_2, O_3, CO, PAN and B_{scat} levels) and wind direction and speed were compiled for each sampling site. After analysis of the sample's mutagenicity, the complete data set was inspected by computer for correlations among the measured variables.

These extraction methods have been shown to deliver >95% of the organic solvent-extractable mutagenic material from even heavily loaded filter samples, and to produce mutagen density and loading values with relative standard deviations of ±15% from separate particulate samples collected in parallel.

B. February 4-7, 1980: Nine Sampling Sites, 12-Hour Resolution over 72 Continuous Hours

This sampling period was initiated during a severe winter smog episode and continued for 72 hours, by which time a Santa Ana condition had developed. The sampling sites (Figure 1) included the eight locations used in the 1979 study (Pitts et al. 1980), namely West Los Angeles, Westwood, Long Beach, California State University Los Angeles (CSULA), Costa Mesa, Claremont, Fontana and Riverside, as well as an additional site, the Haagen-Smit Laboratory in El Monte. Two hi-vol samplers were located at each location in order to provide a "backup" in the event one of the samplers failed or the sample was lost for some other reason. Filters were changed at nominal 12-hour intervals, providing a total of 54 samples (in duplicate) which were analyzed separately for both direct and activatable mutagenicity.

Sampling commenced at 2100 hours PST February 4, 1980 and continued until 2100 PST on February 7, 1980. During the first sampling period NO and NO_2 reached one-hour average concentrations of 750 and 210 ppb, respectively, and the carbon monoxide peak was recorded as 12 ppm as measured at the Los Angeles SCAQMD. The following day was also characterized by severe winter pollution, when the ozone concentration reached 110 ppb in West Los Angeles, and similar conditions prevailed until the evening hours of February 6, when strong winds from the northeast began to sweep the area. During the final sampling period, "clean air" conditions prevailed at several sites; background levels of all of the monitored pollutants were recorded at the inland sites, while the coastal areas showed the impact of direct emissions in moderate levels of CO, NO and NO_2 but little photochemical ozone production. Skies throughout the sampling period were unobscured.

The mutagenicity data for this period showed that, in most cases, direct activity was more intense than the measured activatable mutagenicity (2% S9), in contrast to our July 11-14, 1979, measurements (Pitts et al., 1980). When the data set was split into day (0900-2100 PST) and night (2100-0900 PST) measurements and averaged over the entire sampling period, all sites except Long Beach and Fontana showed higher mutagen density at night. This trend had also been observed at several of the sites during our earlier summer collection. Due to the unstable

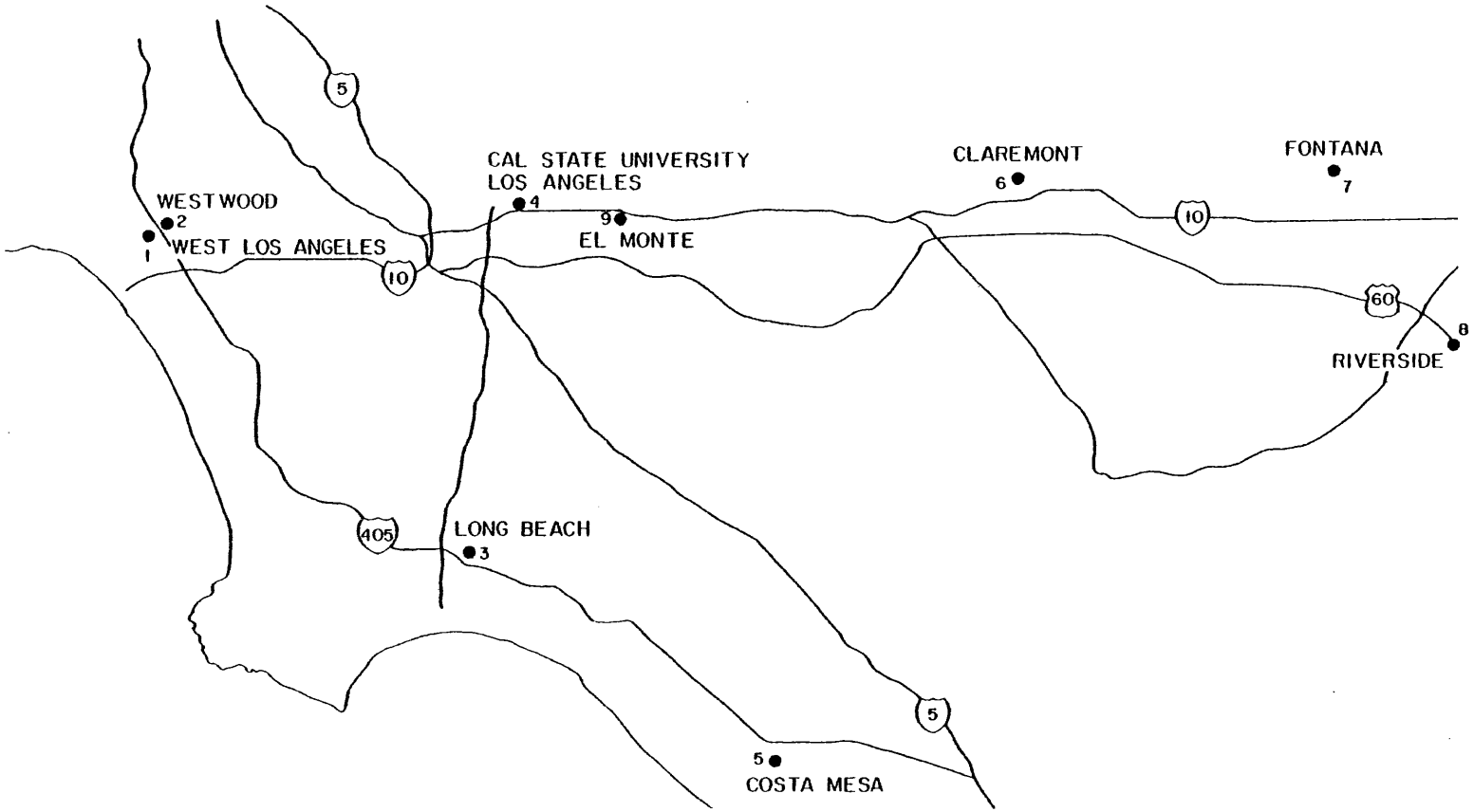

Figure 1. Sampling locations for the study of the geographical and temporal distribution of atmospheric mutagens in the SCAB.

meteorological conditions prevailing during the winter collection, however, these average values are not interpretable in terms of transport phenomena.

The 12-hour resolution obtained in the February study offers more information than a comparable 24-hour collection. Figure 2 shows the 12-hour average direct-acting mutagen densities at the sampling sites during this period, measured using Ames' strain TA98. The values range from a high of 193 rev m^{-3} at CSULA during the first 12-hour sampling period, to very low "clean air" values of less than 10 rev m^{-3} on the final day at several sites. The changes in the mutagenicity parameters clearly reflect the influence of meteorology and air quality observed independently during this period. At the beginning of the sampling period, the pollution episode was largely confined to the primary emission sites near the coast; our trajectory analysis shows that onshore flow during February 5 produced transport to the inland "receptor sites" of the basin. The winds which arose on the night of February 6 and continued during the final sampling period swept the area clean. The levels of pollutant gases which were monitored are also consistent with the meteorology and with the mutagen parameters. A simple Pearson analysis of this data set revealed that both mutagen density and mutagen loading correlated positively with NO, NO_2, and especially CO levels, and that the mutagen loading parameter correlated negatively with ozone concentration.

C. Three-Hour Resolution over 24 Hours at Three Sites, Summer and Winter Collections

These unprecedented high resolution studies produced detailed profiles of the diurnal behavior of airborne particulate mutagenicity during periods representative of "average" days in the SCAB. The diurnal behavior of the levels of the more easily monitored pollutants is well established, so that the measurements reported here can be compared to these other known trends.

The sampling was conducted at three sites; Los Angeles, on the roof of the Physical Science Building of the California State University at Los Angeles (CSULA), in an area of strong primary pollutant emissions; Claremont, on the roof of the Jacobs Science Center of Harvey Mudd College (HMC), representing an intermediate smog receptor site; and Riverside, on

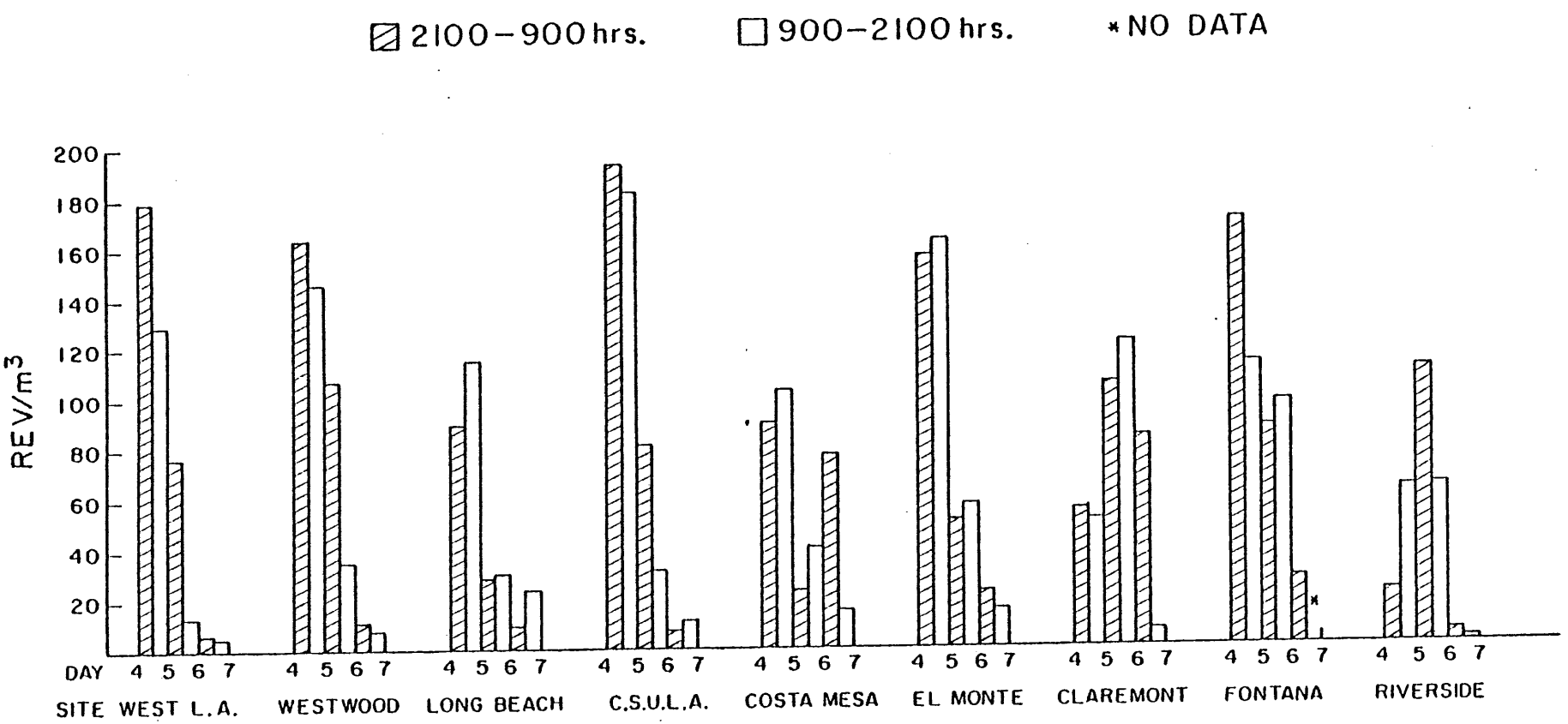

Figure 2. Direct acting mutagen density (revertants/m^3 ambient air) using strain TA98 for total extracts of particulate samples collected using 12-hour periods at nine sites throughout the SCAB, February 4-7, 1980.

the roof of the California Air Resources Board Mobile Laboratory (ARBML) for Air Pollution Research on the University of California campus at Riverside (UCR), a downwind receptor site. Six samplers were installed at each site in order to provide sufficient sample for Ames assay. Filters on five of these samplers were changed at three-hour intervals, while the sixth collected a 24-hour composite sample for comparison purposes. Extraction of three of the short-term filters gave enough material for Ames testing; the remaining two filters served as backup or archival samples.

Ames testing was carried out using strain TA98, which has consistently exhibited the strongest response for extracts of ambient POM of any of the commonly used strains. Air quality parameters were determined at each collection site, with the addition of PAN and b_{scat} measurements, and air mass trajectories were plotted for three hour intervals in order to correspond with the resolution of the mutagenicity measurements.

Four sample sets were collected, on July 29, September 12 and September 17, 1980 and during March 11-12, 1981. The first three sampling periods were initiated at 0000 hours PST, while the last was begun at 1200 hours PST. The July 29 sample was incomplete due to electrical failures at two of the sites, and was not analyzed.

1. September 12, 1980

Onshore flow prevailed at all sites throughout this sampling period. The day was characterized by a moderate summer-type smog episode, with an ozone level of 232 ppb (half hour average) recorded at Claremont. The mutagen densities at each site, with and without metabolic activation, are plotted in Figures 3 and 4 as a function of time of day. In contrast to the February 4-7, 1980 collection results and in agreement with our 1979 summer study, the samples showed increased activity in the presence of mammalian metabolic enzymes. As anticipated, the mutagen density varied substantially during the day, the effect being most pronounced in Claremont where the 0600-0900 PST hours sample exhibited three times the activity of the 1200-1500 PST hours sample.

Similar trends in the diurnal behavior of mutagen density were observed at each site. The values generally fell during the 0000-0600 hour PST period, rose sharply during the morning, fell to a minimum during the early afternoon, and rose again around 1800 PST. Comparison of the

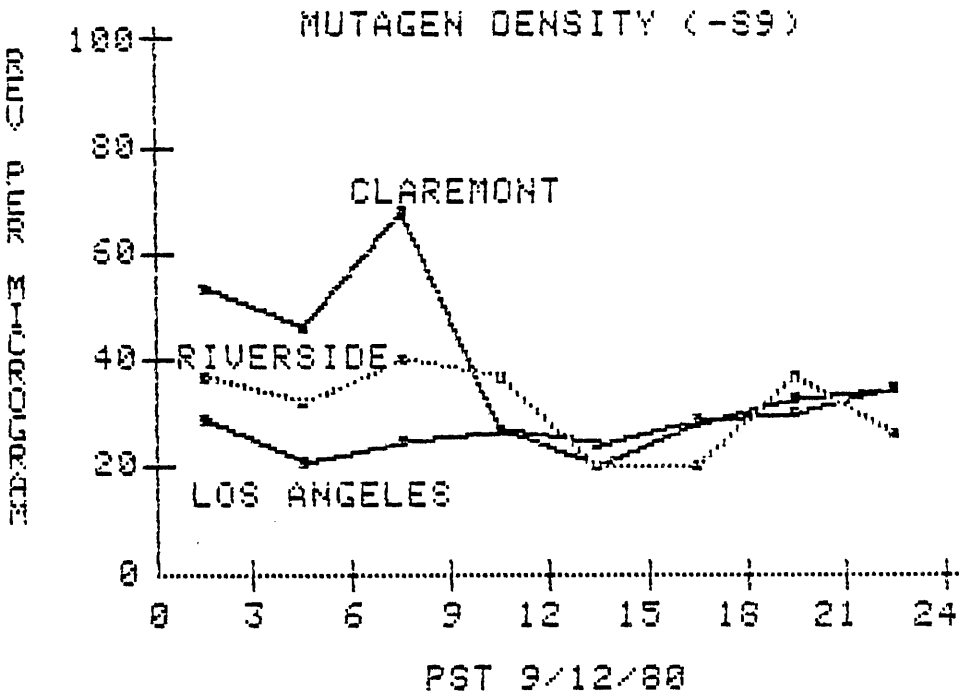

Figure 3. Diurnal variation of direct-acting mutagen density, September 12, 1980

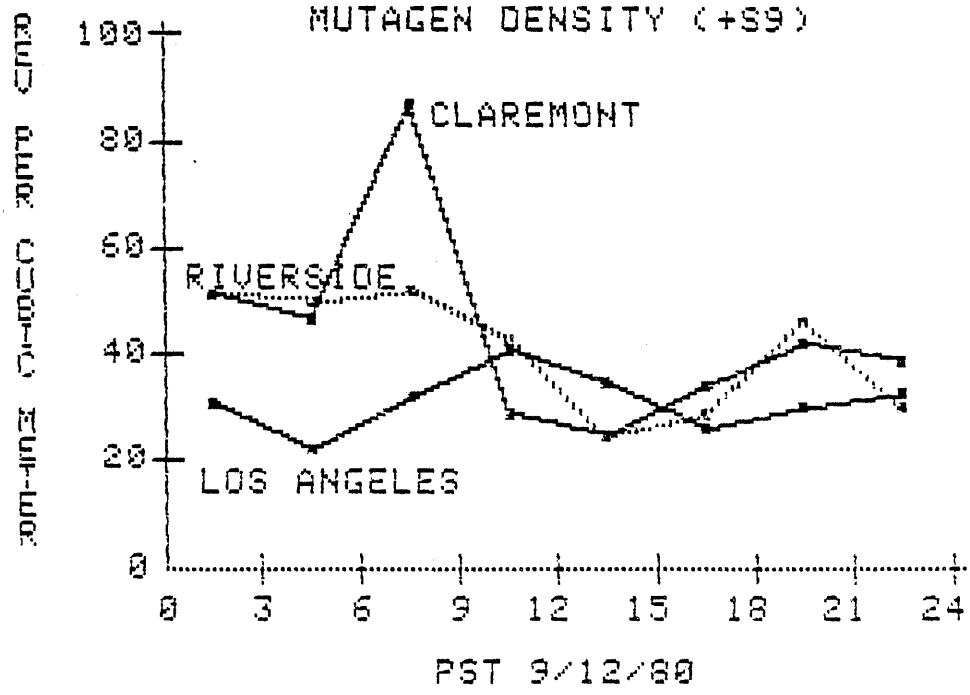

Figure 4. Diurnal variation of activatable mutagen density, September 12, 1980

24-hour average mutagen densities derived from the long term samples with those obtained by summing the 3-hour values showed a good correspondence at the Claremont site, but the long-term samples collected at Riverside and Los Angeles gave lower values than the composite of short term samples. This difference, which amounted to ~33% in both cases, is not statistically significant, however. The mutagenicity measurements again correlated positively with NO, NO_2 and CO concentrations, and negatively with O_3 levels.

This sample set was tested using a newly developed Ames Salmonella strain, TA98NR, which is similar to TA98 but lacks the bacterial metabolism responsible for the strong "direct" mutagenicity of simple nitroarenes such as 2-nitrofluorene and 1-nitropyrene toward TA98 (Rosenkranz and Speck 1975, 1976, Rosenkranz and Poirier 1979, Rosenkranz et al. 1981). The results of this assay indicates that nitroarenes may contribute substantially to the direct mutagenicity of suspended particles in the SCAB.

2. September 17, 1980

Offshore flow prevailed at all sites at the beginning of this sampling period, changing to onshore at approximately 1100 PST. This day was characterized by more severe and widespread photochemical activity, with the ozone level reaching 285 ppb in Claremont and 255 ppb at Riverside at 1500 PST. Plots of mutagen density vs. time of day are presented in Figures 5 and 6. The patterns observed on September 12 were repeated, at higher overall levels. For example, the highest mutagen density occurred at Los Angeles in the early hours of the morning at 180 rev m^{-3} (TA98, +S9) and fell to less than 50 rev m^{-3} between 1200 and 1500 PST. The average mutagen density at this site (24 hour sample) was measured as 71 rev m^{-3}, less than half the peak 3-hour average. Analysis of the 24-hour samples generally showed excellent agreement with the sum of short-term measurements. The worst case, a difference of 30% at Los Angeles, still was statistically insignificant. The pattern of morning peak and afternoon low mutagen densities with a gradual increase in the evening was repeated, as was the increase in mutagenic activity of the POM extracts in the presence of mammalian metabolic enzymes during the rush hours. Analysis of the gas phase pollutant data again showed that the mutagenicity

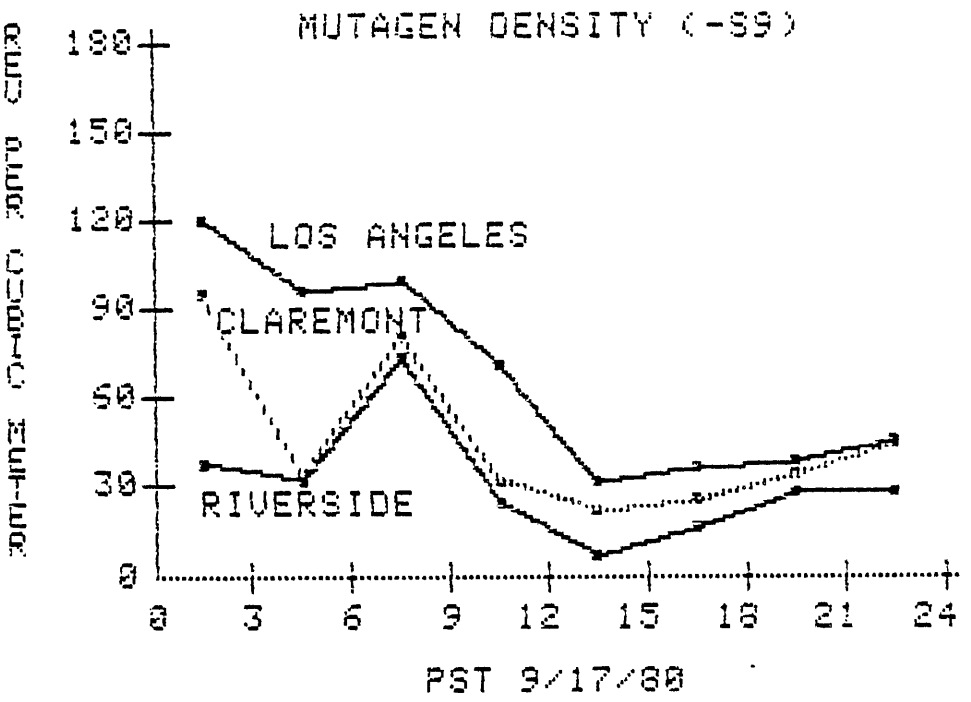

Figure 5. Diurnal variation of direct-acting mutagen density, September 17, 1980

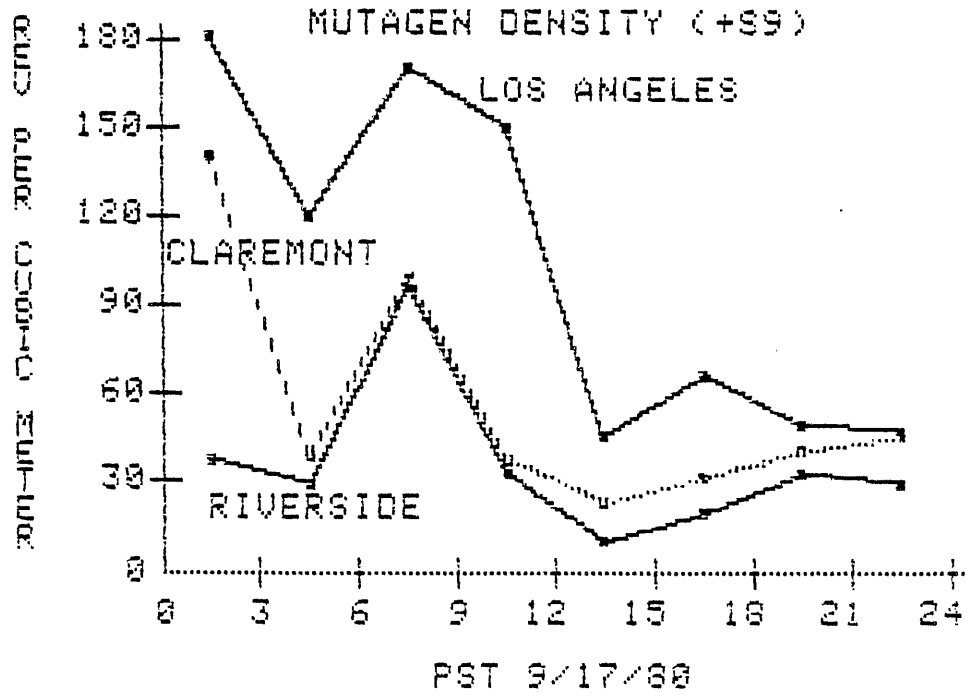

Figure 6. Diurnal variation of activatable mutagen density, September 17, 1980

measurements correlated positively with NO, NO_2 and CO levels and negatively with O_3 concentrations.

3. March 11-12, 1981

This sample set was collected in order to provide data for a day typical of the winter season, when air pollution in the SCAB is often characterized by higher relative humidity, NO_x and PAN levels and less ozone production than during the summer months. The sampling period began at noon on March 11, and the persistent onshore winds during the next twenty-four hours frustrated our attempts to sample "winter smog" on this occasion. Light pollution was indicated by the air quality data at the Los Angeles and Claremont sites; ozone concentrations reached maxima of 98 ppb in Riverside (1500-1600 hours PST), 63 ppb in Claremont (1100-1200 hours PST), and 67 ppb in Los Angeles (1300-1400 hours PST), while NO and NO_2 levels were usually below 50 ppb at all sites. The particulate mutagenicity was also low.

Figures 7 and 8 show the diurnal behavior of mutagen density at the three sites. The most notable features of these diurnal profiles are the prominent peaks occurring during the morning and evening hours, again usually coincident with observable increases in S9 activation. Air quality data used in the linear regression analysis of this data set were obtained from the nearest SCAQMD monitoring station at the Los Angeles and Claremont sites when equipment malfunctioned at the actual sampling positions. While the distance of the measurement stations from the particulate collections and the lower precision of the measurements available from the SCAQMD can be expected to adversely affect the data analysis, the trends observed during the September studies were reproduced fairly well in this analysis. Correlations of NO, NO_2 and CO with mutagen density were significant at the 95% confidence level for the Riverside data (where the air quality data was collected on-site); the relationship with CO was preserved in the Claremont and Los Angeles data sets, but the correspondence between NO_x and mutagenicity was less pronounced. There was a negative correlation of mutgenicity data with ozone despite the lower concentrations of ozone at this time of year.

Overall, the data for this day showed brief periods of mutagen introduction into the atmosphere followed by rapid dispersion and clearance through wind action. It is interesting to note that even during this

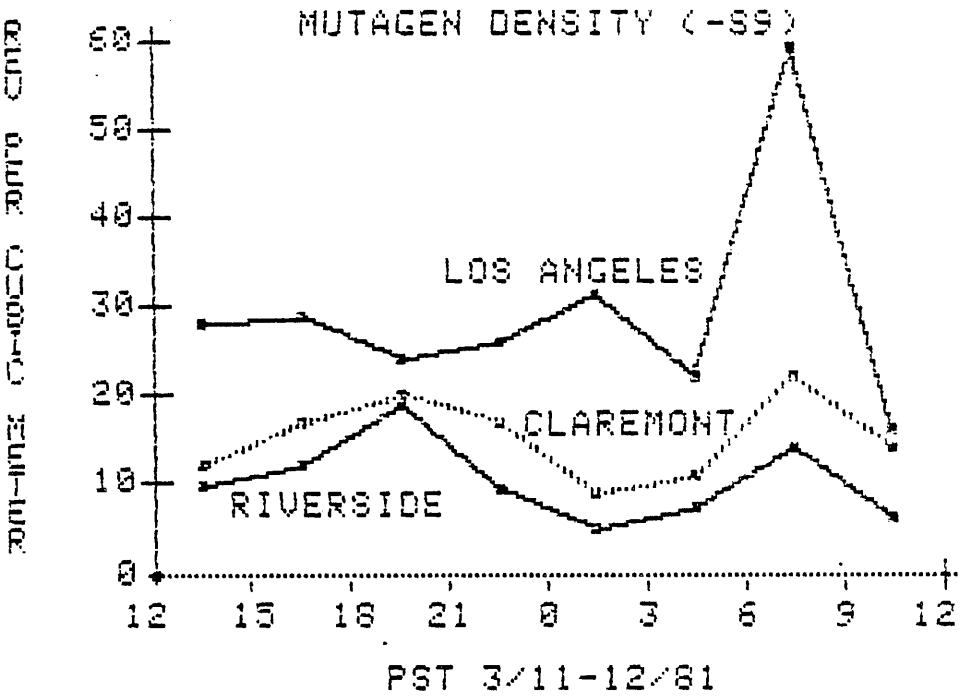

Figure 7. Diurnal variation of direct-acting mutagen density, March 11-12, 1981

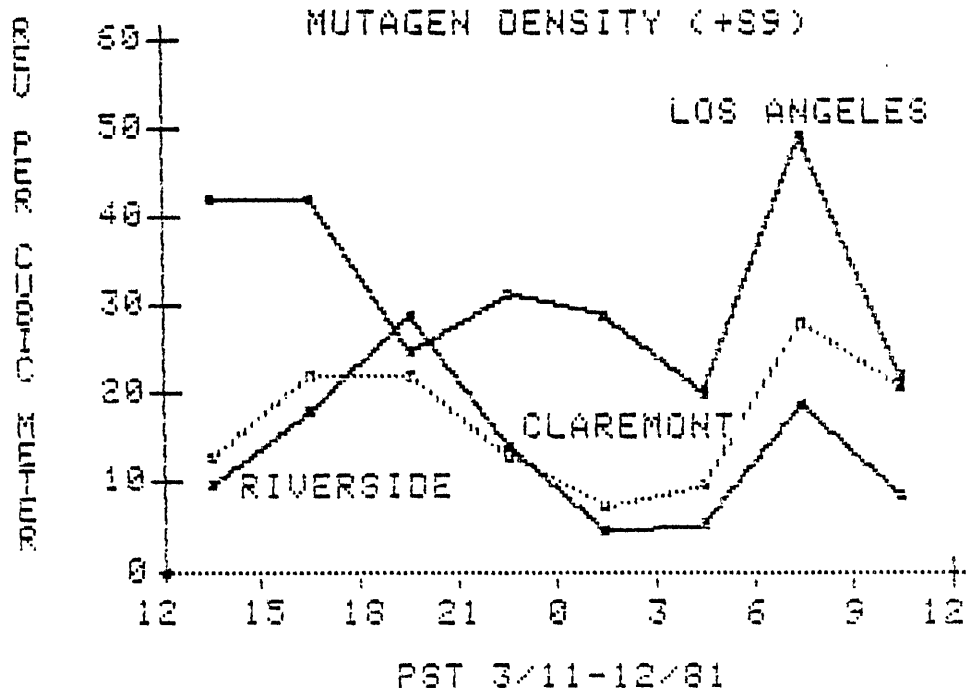

Figure 8. Diurnal variation of activatable mutagen density, March 11-12, 1981

relatively "clean" period the maximum three-hour average mutagen density reached 59 revertants/cubic meter at Los Angeles (600-900 hours PST).

D. Conclusions

We have demonstrated the feasibility of short-term assay of the mutagenic material associated with suspended particulate matter, and have assembled a data base which includes over one hundred such measurements. These assays were conducted using reproducible and sensitive methods which enable quantitative comparison of the intensity of particulate mutagenicity among different air masses. Other more easily measured air quality parameters were compiled during the particulate sampling periods in order to provide a means of evaluating the severity of pollution in more conventional terms and to serve as a data base in a search for relationships among the routinely monitored variables and our mutagenicity measurements.

This effort has revealed several aspects of the geographical and temporal distribution of particulate mutagenicity in the SCAB, and leads us to draw the following conclusions:

- Mobile source emissions appear responsible for the bulk of the mutagenic particulate present in the atmosphere at most locations in the SCAB. This is demonstrated by the good correlations between conventional air quality indicators of such emissions (NO_x, CO, Pb, Br) and mutagen levels, and by the strong gradient in mutagen density observed across the heavily traveled Interstate 405 in West Los Angeles. Some locations in the area show anomalous particulate mutagenicity (Long Beach and Fontana), however, which may reflect local stationary source emissions.

- Particulate mutagenicity displays many of the characteristics of a gas-phase pollutant in terms of its atmospheric residence time, transport behavior, and its response to meteorological conditions such as inversion heights. These features are a result of the low deposition rates characteristic of sub-micron particles.

- Some promutagenic species present in freshly emitted POM appear to be susceptible to rapid destruction or removal from the suspended particulate phase.

- Secondary photochemically-generated aerosol does not appear to contribute substantially to particulate mutagenicity. No significant

correlation was observed between b_{scat} or TSP values and mutagen density. Periods of high gas-to-particle conversion rates and photochemical oxidant generation generally coincided with minima in the diurnal mutagen density and loading curves. This does not mean that particulate organic transformation is unimportant, however.

- Nitroarenes may contribute substantially to the direct mutagenic activity of SCAB suspended particles.
- Carbon monoxide concentration is the best predictor of mutagen density among the routinely monitored air quality parameters.
- Short-term peak particulate mutagenicity is routinely much higher than longer-term average values. This aspect of the problem should be considered in both control strategies and in epidemiology studies designed to detect health effects from this phenomenon. For example, populations exposed to these peak levels, such as commuters, should show such effects most clearly.
- The issue of filter artifacts remains unresolved; although the correspondence between the average of short-term samples and concurrently collected long-term samples was generally very good, the possibility of very rapid formation or destruction of mutagenic species on a sampling filter remains.
- Present levels of particulate mutagenicity in the SCAB lie in the range of 0-200 TA98 revertants/cubic meter using our procedures.

II. TWELVE-HOUR SAMPLING PERIODS: 72-HOUR PROFILE OF THE MUTAGENICITY OF EXTRACTS OF AMBIENT POM COLLECTED FEBRUARY 4-7, 1980

A. Introduction

This analysis was designed to evaluate the feasibility of the high-resolution studies conducted later in the year. Sampling was initiated during a severe "winter smog" episode, and continued for three days, February 4-7, 1980. Particulate mutagenicity measurements were taken at nine locations throughout the Southern California Air Basin over 72 continuous hours with 12-hour resolution. As was the case in our 1979 study, filters were changed at 12-hour intervals. Each filter was analyzed separately in this case, however, in order to obtain improved temporal resolution.

B. Sampling Procedures and Sites

An additional site was added to the eight used in the 1979 studies (Pitts et al., 1980); a set of hi-vols was located at the Haagen-Smit Laboratory in El Monte giving an additional receptor site between California State University at Los Angeles (CSULA) and Harvey Mudd College in Claremont. The samplers were situated on the roof of an air monitoring station on the southwest corner of the Haagen-Smit Laboratory approximately 4 m above the parking lot. Some localized diesel truck emissions could be expected from the warehouse immediately to the west. The upwind (based on prevailing westerly winds) West Los Angeles freeway site used to investigate vehicular emission was relocated when the building used as the original site was demolished. The replacement area was at the back fence of the National Guard Armory, about 200 m southwest of the original site. All the sampling locations are shown in Figure 1.

In summary, the locations were chosen as follows: West Los Angeles (WLA) for vehicular emissions, Long Beach (LB) for petroleum refineries emissions, Costa Mesa (CM) for power plant emissions, Fontana (F) for steel mill emissions and CSULA (LA), El Monte (EM), Claremont (C) and Riverside (R) as receptor sites of increasing distance from the major primary emission sources.

Two standard hi-vol samplers (Sierra Model 305-2000) were located at each site. By means of a special adapter the exhaust from the motor housing was routed away from the sampler intake with 5 m of 4" dryer

ducting. Sampling rates were set and maintained at 40 SCFM by use of a Sierra Model 330 orifice plate flow measuring device and Sierra Model 310 mass flow controllers.

Teflon-impregnated glass fiber filters (Pallflex T60A20) were used for the particulate collections. This filter type was chosen for its presumed inertness (although comparison studies conducted during the previous grant period showed no artifact that could be ascribable to this quality), low organic background and ease of extraction. Prior to use all filters were thoroughly extracted with CH_2Cl_2 and CH_3OH, dried under vacuum, equilibrated at 75°F and 50% RH, weighed, wrapped in aluminum foil, and placed in file folders. After collection, the loaded filters were re-equilibrated at 75°F and 50% RH, reweighed to determine particulate loadings, and placed in a -20°C freezer to await extraction.

The hi-vols were run on a day (0900-2100 hrs PST) and night (2100-0900 hrs PST) basis in order to make a distinction between a daytime atmosphere which is highly oxidizing and reactive in nature and a nighttime atmosphere which is higher in primary, untransformed pollutants. Since one person was assigned two sites the actual filter change time varied by ± 1/2 hour.

Each of the 12-hour day and night samples from these collections were not combined for processing as had been done in year one, but treated separately. This revision was made for two reasons. First, an estimate was needed of the number of hi-vols necessary during the short-term, three-hour collections. When using short-term collections, enough samplers must be run simultaneously to yield sufficient material for the chemical and mutagenic assays. One sampler operated for 12 hours will collect approximately as much particulate matter as four three-hour samples collected in parallel. Thus, if one filter from the 12-hour collections yielded sufficient material for this study, then the short-term collections could be carried out with five hi-vols at each site (the additional hi-vol was added as backup in case of mechanical failure or during periods of light pollution). Second, keeping the 12-hour samplers separate would allow the compilation of a three-day profile of the mutagenic activity of ambient particles collected in the South Coast Air Basin. These data could show both the day-to-day variation in mutagenic activity and changes between day and night samples and when coupled with other ambient air

quality measurements, could yield clues concerning the sources and potential transformation of particulates containing mutagenic components.

C. Extraction and Sample Handling Procedures

The unexposed edges of each filter were trimmed, and the particulate-laden remainder was extracted by ultrasonic agitation with two 150 ml portions of a 1:1:1 (v/v/v) mixture of methanol, dichloromethane and toluene at 35°C. The residual solids and extraction flask were rinsed three times with a small additional amount of solvent (~25 ml), and the extract was filtered through a 0.5 micron fluoropore filter into a 500 ml round-bottomed flask. The bulk of the solvent was removed *in vacuo* (35°, > 20 Torr) and the residue was transferred to a tared amber vial sealed with a Teflon-faced silicone septum. Each sample was dried to constant (± 1%) weight under a gentle stream of nitrogen gas at 35-40°C. The samples were then transferred to our microbiology laboratory for Ames assay. All sample manipulation was performed under red or yellow light to avoid photochemically-induced composition changes. The sample volumes and gravimetric data from this collection are given in Table 1.

D. Preliminary Mutagen Assay

Preliminary testing of the extracts' mutagenicity toward Ames *S. typhimurium* strains TA98, TA100, TA1535, TA1537 and TA1538 at various S9 levels indicated that strain TA98 was the most responsive to the samples tested and that linear dose responses were obtained at sample levels of 0.1-100 µg/plate. The addition of S9 to the test plates was observed to cause suppression of mutagenic activity for most of the samples. In those cases where S9 activation was observed, a 2% level provided the optimum response. For the quantitative testing, the samples were plated in triplicate with Ames' strain TA98 at dose levels of 1, 10, 20, 40, 80, 100, 150, 200 and 400 µg/plate, with and without 2% S9. During each test, TA98 was checked to determine that the strain maintained sensitivity to UV light and crystal violet, and resistance to ampicillin. Dose-responses to the standard control mutagens 2-nitrofluorene (2-NF), 2-aminoanthracene (2-AA) and benzo(a)pyrene (BaP) were determined in parallel with the ambient samples. Response to these standards showed good agreement on the two mutagen assay test days: 2-NF gave 490 and 460 (± 20) rev/µg/plate

Table 1. Sample Volumes and Gravimetric Data for the February 4-7, 1980, Particulate Samples

Sample Location	Interval*	Air Volume (m^3)	Particulate Mass (mg)	Extract Mass (mg)	Total Suspended Particulate ($\mu g/m^3$)
West Los Angeles	4N	816	110.3	80.477	135
	5D	801	115.8	67.201	145
	5N	799	76.8	41.286	96
	6D	796	91.6	13.085	115
	6N	821	52.8	7.236	64
	7D	792	52.2	7.170	66
Westwood	4N	816	106.2	52.346	130
	5D	797	153.4	72.969	192
	5N	809	83.9	43.366	104
	6D	809	164.7	17.232	204
	6N	892	57.4	8.668	64
	7D	792	58.7	7.835	74
Long Beach	4N	769	73.6	38.563	96
	5D	855	145.9	64.289	171
	5N	770	62.9	28.081	82
	6D	843	146.1	30.339	173
	6N	755	74.9	6.807	99
	7D	806	84.7	15.619	105
CSULA	4N	883	143.9	73.927	163
	5D	731	132.5	71.465	181
	5N	814	110.6	53.753	136
	6D	805	127.2	38.254	158
	6N	815	108.7	8.026	133
	7D	787	76.5	9.991	97
Costa Mesa	4N	855	97.5	51.190	115
	5D	763	76.6	38.157	100
	5N	866	72.2	35.134	83
	6D	758	127.5	41.373	168
	6N	906	149.3	38.720	165
	7D	806	85.0	16.148	105
El Monte	4N	844	212.4	75.624	252
	5D	758	164.8	70.016	217
	5N	816	90.6	48.250	111
	6D	803	171.1	54.223	208
	6N	798	154.4	32.177	193
	7D	788	66.0	11.777	84

(continued)

Table 1 (continued)

Sample Location	Interval*	Air Volume (m^3)	Particulate Mass (mg)	Extract Mass (mg)	Total Suspended Particulate ($\mu g/m^3$)
Claremont	4N	770	64.0	38.986	83
	5D	838	144.8	72.891	173
	5N	758	117.0	76.254	154
	6D	877	274.4	160.734	313
	6N	747	187.8	64.841	251
	7D	781	50.1	6.765	64
Fontana	4N	838	204.3	106.902	244
	5D	783	205.7	94.848	263
	5N	838	126.1	72.706	150
	6D	787	356.9	177.347	453
	6N	865	119.7	44.839	138
	7D	-	-	-	-
Riverside	4N	818	23.9	5.575	29
	5D	816	108.2	57.239	133
	5N	803	186.7	126.786	233
	6D	816	223.9	145.783	274
	6N	795	97.9	15.293	123
	7D	792	49.9	3.823	63

*Arabic numeral indicates date of collection; D = day interval (0900-2100 PS); N = night interval (2100-0900 PST).

over a range of 0-1 µg/plate in the absence of S9 on May 19 and 28, 1980, respectively; 2-AA gave a nonlinear (S-shaped) dose response over a range of 0-2 µg/plate at 2% S9 concentration, producing 5621 ± 138 revertants at 1.5 µg/plate on May 19, 1980 and 5988 ± 168 revertants at the same dose on May 27, 1980 and was inactive in the absence of S9. Benzo(a)pyrene, tested at dose levels of 0.25, 0.5, 0.75, 1.0, 1.5, 2.0 and 5.0 µg/plate in the presence of 2% S9, also produced nonlinear response curves. The number of revertants produced at doses of 0.75 and 1.0 µg/plate differed between the two days, but activities at higher and lower doses compared favorably. At 0.5 µg/plate, BaP produced 126 ± 8 revertants on May 19, 1980 and 140 ± 12 revertants on May 24, 1980.

Dose-response data for this study were reduced to sample specific activity by means of a recently implemented computer program. The average

and standard deviation of untreated control plates were calculated to estimate the background count (number of spontaneous reversions). The counts of the treated plates were adjusted by a Biotran calibration curve, averaged and corrected for spontaneous background. The standard norm for the mean at each concentration was also calculated over several ranges of concentration to determine the linear portion.

For the following calculations, let

y_o = average background count

b_o = number of plates for background calculation

s_o = standard deviation of background plates

o_i = raw count for i^{th} plate

z_i = $f(p_i)$ according to calibration curve

n_p = number of plates at each concentration

The plate count and standard deviation at each concentration are:

$$\bar{z} = \frac{\Sigma z_i}{n_p} \qquad s_z = \sqrt{\frac{\Sigma z^2 - \frac{(\Sigma z)^2}{n_p}}{n_p - 1}}$$

The adjusted count and standard error of the mean are:

$$y = \bar{z} - \bar{\bar{y}_o}$$

$$s_{\bar{z} - \bar{y}_o} = \sqrt{\frac{s_z^2}{n_p} - \frac{s_o^2}{n_o}}$$

The slope (specific activity) and intercept of the dose-response relation were calculated by the usual linear regression equations.

$$\text{specific activity} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}$$

$$\text{intercept} = \frac{\Sigma y}{n} - \text{activity} \frac{\Sigma x}{n}$$

y = adjusted plate count at x

n = number of concentration levels tested.

This procedure was carried out initially using all of the Ames test data. The calculated fit was then compared to the raw data as displayed on the video terminal, and an operator then instructed the program to eliminate those points which did not correspond to the linear region.

These mutagenicity data are presented in Table 2.

E. Air Quality and Air Mass Trajectory Measurements

Except at the El Monte site the ambient air quality data were compiled from the following nearby South Coast Air Quality Management District (SCAQMD) monitoring stations: West Los Angeles, SCAQMD 086; Long Beach, SCAQMD 072; downtown Los Angeles, SCAQMD 987; Costa Mesa, SCAQMD 3192; Pomona, SCAQMD 075; Fontana, SCAQMD 5176; Riverside, SCAQMD 4144. Air quality data at El Monte was obtained from an instrumented trailer at the ARB Haagen-Smit Laboratory. These data are shown in Tables 3 through 8.

In order to obtain information about the origin of the sampled air and the prevailing wind direction during the sampling period, wind direction and velocity data from monitoring stations throughout the SCAB were compiled and used to back-calculate trajectories of the sampled air masses. The procedure used was as follows:

(1) The sampling interval was divided into six two-hour segments.

(2) Each trajectory was calculated by moving backwards in hourly intervals from the chronological termination point (the collection site). At each point on the trajectory (x_t, y_t, t), the wind speed and direction data for the previous hour at the three closest monitoring stations were used to calculate a vector with the closer stations receiving a proportionately higher mathematical weighting. The new coordinates for t_{t-1}, y_{t-1} were then calculated from this vector.

(3) This process was repeated for the next previous hour using another set of coordinates.

(Text begins again on page 47)

Table 2. Mutagen Assay Data for the February 4-7, 1980 Particulate Samples.

Sample Location	Interval	Specific Activity TA98 rev/µg Extract		Mutagen Density rev/m^3		Mutagen Loading rev/µg Particulate	
		-S9	+S9(2%)	-S9	+S9(2%)	-S9	+S9(2%)
West Los Angeles	4N	1.82	1.33	179	131	1.33*	0.97*
	5D	1.54	1.15	129	96	0.89	0.67
	5N	1.48	1.28	76	66	0.80	0.69
	6D	0.81	0.93	13	15	0.12	0.13
	6N	0.62	0.37	5.5	3.3	0.085	0.051
	7D	0.52	0.63	4.7	5.7	0.071	0.087
	Mean, night values			87	67	0.74	0.57
	Mean, day values			49	39	0.36	0.30
Westwood	4N	2.55	2.16	164	139	1.26	1.06
	5D	1.60	1.73	146	158	0.76	0.82
	5N	1.99	2.13	107	114	0.76	0.82
	6D	1.62	2.07	35	44	0.17	0.22
	6N	1.16	0.83	11	8.1	0.18	0.13
	7D	0.82	1.43	8.1	14	0.11	0.19
	Mean, night values			94	87	0.82	0.76
	Mean, day values			63	72	0.34	0.41
Long Beach	4N	1.77	1.36	89	68	0.93	0.71
	5D	1.52	1.24	114	93	0.67	0.55
	5N	0.78	0.79	28	29	0.35	0.35
	6D	0.84	0.89	30	32	0.17	0.18
	6N	1.05	1.16	9.5	10	0.095	0.11
	7D	1.20	1.42	23	28	0.22	0.26
	Mean, night values			42	36	0.46	0.39
	Mean, day values			56	51	0.35	0.33

Table 2 (continued) - 2

Sample Location	Interval	Specific Activity TA98 rev/μg Extract		Mutagen Density rev/m^3		Mutagen Loading rev/μg Particulate	
		-S9	+S9(2%)	-S9	+S9(2%)	-S9	+S9(2%)
CSULA	4N	2.30	2.05	193	172	1.2	1.05
	5D	1.86	1.40	182	137	1.0	0.74
	5N	1.23	1.07	81	71	0.60	0.52
	6D	0.68	0.93	32	44	0.20	0.28
	6N	0.73	1.16	7.2	11	0.054	0.086
	7D	0.84	1.31	11	17	0.11	0.17
	Mean, night values			94	85	0.62	0.55
	Mean, day values			75	66	0.44	0.40
Costa Mesa	4N	1.49	1.16	89	69	0.79	0.61
	5D	2.04	1.89	102	95	1.02	0.94
	5N	0.57	0.66	23	27	0.28	0.32
	6D	0.73	0.82	40	45	0.24	0.27
	6N	1.80	1.80	77	77	0.47	0.47
	7D	0.75	0.89	15	18	0.14	0.17
	Mean, night values			63	58	0.51	0.47
	Mean, day values			52	53	0.47	0.46
El Monte	4N	1.74	1.53	156	137	0.62	0.54
	5D	1.75	1.16	162	107	0.74	0.49
	5N	0.85	1.04	50	61	0.45	0.55
	6D	0.84	0.88	57	59	0.27	0.28
	6N	0.55	0.69	22	28	0.11	0.14
	7D	1.03	1.32	15	20	0.18	0.24
	Mean, night values			76	75	0.39	0.41
	Mean, day values			78	62	0.40	0.34

Table 2 (continued) - 3

Sample Location	Interval	Specific Activity TA98 rev/µg Extract		Mutagen Density rev/m^3		Mutagen Loading rev/µg Particulate	
		-S9	+S9(2%)	-S9	+S9(2%)	-S9	+S9(2%)
Claremont	4N	1.08	0.75	55	38	0.66	0.46
	5D	0.58	0.45	50	39	0.29	0.23
	5N	1.04	1.10	105	111	0.68	0.72
	6D	0.66	0.73	121	134	0.39	0.43
	6N	0.96	0.96	83	83	0.33	0.33
	7D	0.75	1.29	7	11	0.10	0.17
	Mean, night values			81	77	0.49	0.50
	Mean, day values			59	61	0.26	0.28
Fontana	4N	1.33	1.07	170	136	0.70	0.56
	5D	0.93	0.72	113	87	0.43	0.33
	5N	1.00	0.95	87	78	0.58	0.52
	6D	0.43	0.29	97	65	0.21	0.14
	6N	0.53	0.47	27	24	0.20	0.18
	Mean, night values	-	-	-	-	-	-
	Mean, day values			95	79	0.49	0.42
Riverside	4N	3.10	2.89	21	20	0.72	0.67
	5D	0.88	0.76	62	53	0.47	0.40
	5N	0.69	0.79	109	125	0.47	0.54
	6D	0.35	0.28	63	50	0.23	0.18
	6N	0.25	0.27	4.8	5.2	0.039	0.042
	7D	0.48	0.40	2.3	1.9	0.037	0.031
	Mean, night values			45	45	0.41	0.42
	Mean, day values			42	35	0.25	0.20

*TSP value obtained from duplicate sample

Table 3. Air Quality Data for February 4, 1980, Night Collection
(2100 Hours PST 2/4/80 to 900 Hours PST 2/5/80)

Site	SCAQMD Station[a]	CO (ppm) Mean	CO (ppm) Peak	SO_2 (ppb) Mean	SO_2 (ppb) Peak	NO_2 (ppb) Mean	NO_2 (ppb) Peak	NO (ppb) Mean	NO (ppb) Peak	O_3 (ppb) Mean	O_3 (ppb) Peak
Long Beach	072	5.3	9	14	20	56	70	150	280	5.8	10
Pomona	075	5.5	10	10	10(11)[b]	70	170	150	390	16	20
West Los Angeles	086	9.3	20	11	20(11)	77	90(10)	260	370	11	20
Downtown Los Angeles	987	8.8	12	17	20	140	210	440	750	13	20
Costa Mesa	3192	2.2	5	1.6	10	14	20(10)	NO DATA		0	0
Riverside	4144	2.3	4	0.8	10	32	40	110	200	1.7	10
Fontana	5176	5.6	6(11)	0	0	77	110(11)	19	30(11)	15	50(11)
El Monte	C	NO DATA		16	30	74	90	240(11)	350(11)	12	20

[a]South Coast Air Quality Management District Monitoring Station Identification Number.
[b]Numbers in parentheses denote the number of hourly measurements included in the tabulation in cases of incomplete data sets, and apply to the mean as well as peak listing.
[c]Data obtained from the ARB Haagen-Smit Laboratory.

Table 4. Air Quality Data for February 5, 1980, Day Collection
(0900 to 2100 Hours PST 2/5/80)

Site	SCAQMD Station[a]	CO (ppm) Mean	CO (ppm) Peak	SO_2 (ppb) Mean	SO_2 (ppb) Peak	NO_2 (ppb) Mean	NO_2 (ppb) Peak	NO (ppb) Mean	NO (ppb) Peak	O_3 (ppb) Mean	O_3 (ppb) Peak
Long Beach	072	6.3	10	38	90(11)[b]	170	310(11)	150	340(11)	12	40
Pomona	075	4.8	8(9)	9.2	30	110	220(11)	78	170(11)	24	50
West Los Angeles	086	5.8	20	15	30	180	340	110	620	41	110
Downtown Los Angeles	987	5.7	8	10	10	210	330	64	270	28	80
Costa Mesa	3192	2.6	5(11)	23	40	NO DATA		NO DATA		18	40
Riverside	4144	3.7	7	7.5	20	79	200	49	170	37	80
Fontana	5176	5.9	8(8)	10	10	100	250	33	60	48	70
El Monte	C	NO DATA		18	40	49	70	66	190	23	70

[a]South Coast Air Quality Management District Monitoring Station Identifcation Number.
[b]Numbers in parentheses denote the number of hourly measurements included in the tabulation in cases of incomplete data sets, and apply to the mean as well as peak listing.
[c]Data obtained from the ARB Haagen-Smit Laboratory.

Table 5. Air Quality Data for February 5, 1980, Night Collection
(2100 Hours PST 2/5/80 to 0900 Hours PST 2/6/80)

Site	SCAQMD Station[a]	CO (ppm) Mean	CO (ppm) Peak	SO_2 (ppb) Mean	SO_2 (ppb) Peak	NO_2 (ppb) Mean	NO_2 (ppb) Peak	NO (ppb) Mean	NO (ppb) Peak	O_3 (ppb) Mean	O_3 (ppb) Peak
Long Beach	072	2.4	5	30	50	58	90	24	90	NO DATA	
Pomona	075	-	9(1)[b]	12	20	120	200	160	270	16	20
West Los Angeles	086	4.5	6	6.7	30	94	120(11)	150	220(11)	7.8	10
Downtown Los Angeles	987	3.7	6	13	20	97	140	170	250	2.5	10
Costa Mesa	3192	1.4	2	5.0	10	NO DATA		NO DATA		28	50
Riverside	4144	5.6	7	0.8	10	86	160	180	280	13	20
Fontana	5176	4.8	6	8.3	10	110	170	26	40	13	30
El Monte	C	NO DATA		10	10	38	50	63	100	<10	<10

[a]South Coast Air Quality Management District Monitoring Station Identifcation Number.
[b]Numbers in parentheses denote the number of hourly measurements included in the tabulation in cases of incomplete data sets, and apply to the mean as well as peak listing.
[c]Data obtained from the ARB Haagen-Smit Laboratory.

Table 6. Air Quality Data for February 6, 1980, Day Collection (0900 to 2100 Hours PST 2/6/80)

Site	SCAQMD Station[a]	CO (ppm) Mean	CO (ppm) Peak	SO_2 (ppb) Mean	SO_2 (ppb) Peak	NO_2 (ppb) Mean	NO_2 (ppb) Peak	NO (ppb) Mean	NO (ppb) Peak	O_3 (ppb) Mean	O_3 (ppb) Peak
Long Beach	072	3.3	5	36	80(11)[b]	96	140(11)	55	120(11)	18	20(9)
Pomona	075	7.1	9	17	30	170	200(11)	130	270(11)	43	100
West Los Angeles	086	1.6	3	7.3	30(11)	53	110	24	90	29	40
Downtown Los Angeles	987	2.0	7	7.5	20	79	180	43	250	18	40
Costa Mesa	3192	1.3	3	13	30(11)	55	70(10)	13	70(10)	35	70
Riverside	4144	4.5	7	12	20(5)	110	160	58	180	73	150
Fontana	5176	6.5	8	13	20	150	200	24	50	86	150(9)
El Monte	C	NO DATA		10	20	38	60	31	100	33	80

[a]South Coast Air Quality Management District Monitoring Station Identifcation Number.
[b]Numbers in parentheses denote the number of hourly measurements included in the tabulation in cases of incomplete data sets, and apply to the mean as well as peak listing.
[c]Data obtained from the ARB Haagen-Smit Laboratory.

Table 7. Air Quality Data for February 6, 1980, Night Collection
(2100 Hours PST 2/6/80 to 0900 Hours PST 2/7/80)

Site	SCAQMD Station[a]	CO (ppm) Mean	CO (ppm) Peak	SO_2 (ppb) Mean	SO_2 (ppb) Peak	NO_2 (ppb) Mean	NO_2 (ppb) Peak	NO (ppb) Mean	NO (ppb) Peak	O_3 (ppb) Mean	O_3 (ppb) Peak
Long Beach	072	1.3	3	0.8	10	22	60	05	50	20	30
Pomona	075	4.6	9(11)[b]	9.2	10	73	100	120	280	13	20
West Los Angeles	086	1.3	2	1.6	10	9.2	30	2.5	20(11)	33	40
Downtown Los Angeles	987	0.5	1	0	0	30	40(11)	9.1	30	12	20
Costa Mesa	3192	1.7	3(11)	0	0	48	60(11)	130	220	0	0
Riverside	4144	1.6	5	10	10	22	90	36	110	33	40
Fontana	5176	3.1	5	2.5	10	24	120	23	30	48	50
El Monte	C	NO DATA		<10	10	30	60	100	290	12	20

[a]South Coast Air Quality Management District Monitoring Station Identifcation Number.
[b]Numbers in parentheses denote the number of hourly measurements included in the tabulation in cases of incomplete data sets, and apply to the mean as well as peak listing.
[c]Data obtained from the ARB Haagen-Smit Laboratory.

Table 8. Air Quality Data for February 7, 1980, Day Collection
(0900 to 2100 Hours PST 2/7/80)

Site	SCAQMD Station[a]	CO (ppm) Mean	CO (ppm) Peak	SO_2 (ppb) Mean	SO_2 (ppb) Peak	NO_2 (ppb) Mean	NO_2 (ppb) Peak	NO (ppb) Mean	NO (ppb) Peak	O_3 (ppb) Mean	O_3 (ppb) Peak
Long Beach	072	2.2	4	8	10(10)[b]	66	90(11)	44	90(11)	11	20(11)
Pomona	075	3	4	0	0	11.2(10)	11	20(10)	29	50	
West Los Angeles	086	1.5	3	5	10	3.7	60	22	30	24	40
Downtown Los Angeles	987	0.84	1	0	0	3.3	60	14	40	21	40
Costa Mesa	3192	1	1(11)	6	10	1.9	30	10	20	14	30
Riverside	4144	1	1	1	10(5)	1.2	20	22	30	28	30
Fontana	5176	3	3	0	0	0	0	15	20	50	50
El Monte	C	NO DATA		<10	10(11)	1.2	30	14	60	28	40

[a]South Coast Air Quality Management District Monitoring Station Identifcation Number.
[b]Numbers in parentheses denote the number of hourly measurements included in the tabulation in cases of incomplete data sets, and apply to the mean as well as peak listing.
[c]Data obtained from the ARB Haagen-Smit Laboratory.

(4) The hourly coordinates of the trajectory were backplotted for 24 hours or until no stations were deemed close or a mountain range or the ocean was reached.

These trajectories are plotted in Figures 9 through 14 for the six 12-hour sampling periods.

F. Discussion

The 36-hour mean particulate mutagen densities during the day (0900-2100 PST) and night (2100-0900 PST) collection periods for the nine sampling stations are plotted in Figure 15. This presentation corresponds to the results which would have been obtained if the "winter" sample had been treated in the same way as our previous "summer" sample (i.e., grouping of the six sample filters at each site into "day" and "night" sample sets) as reported in the final report for year one (Pitts et al., 1980; see Figure 16). Comparisons of the mutagenicity data from the two collections (July 1979 vs. February 1980) reveals several differences:

(1) The direct-acting mutagen density was significantly higher (200-300%) during the winter collection period; response of the standard direct mutagen 2-nitrofluorene was statistically identical in each experiment, so that this difference cannot be ascribed to any change in the sensitivity of TA98.

(2) The average measured activity in the presence of S9 was lower than the direct activity at most of the sites for the winter samples, in contrast to the summer assay results which displayed higher mutagenic activity in the presence of S9. This effect is probably due to several factors, including the high level of direct activity in the winter samples and an apparent change in sensitivity of the TA98/S9 system to activatable mutagens such as BaP. The response of TA98 to BaP in the presence of 2% S9 was lower during analysis of the winter samples. Whether this is ascribable to changes in the sensitivity of the bacterial strains or to differences between S9 lots used for these experiments is not clear.

(3) The geographical variation of the 36-hour (day and night) average mutagen density values was much less pronounced during the winter

(Text beings again on page 56)

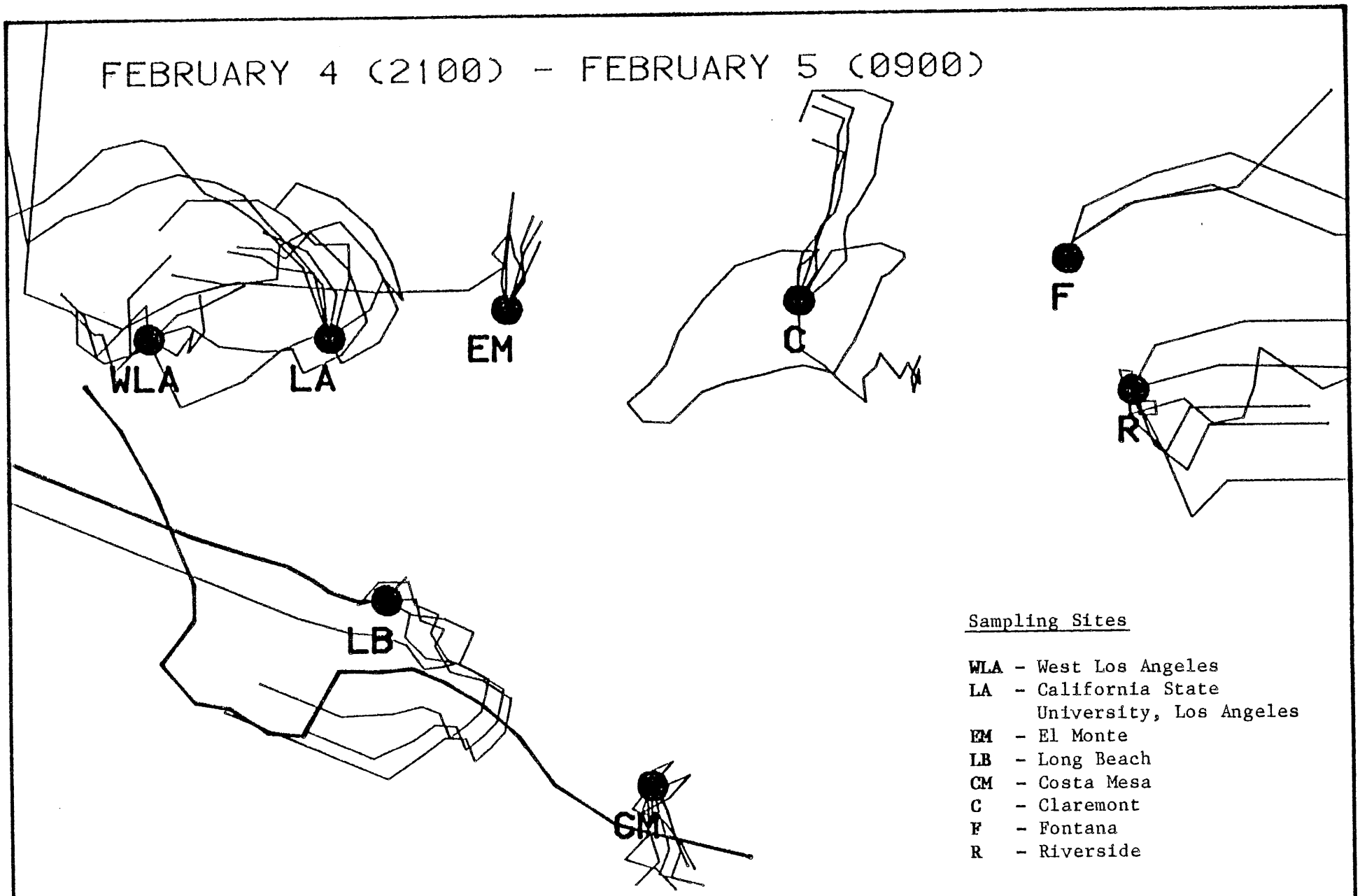

Figure 9. Air mass trajectories for the 12-hour sampling period February 4 (2100) - February 5 (0900) [4N], 1980.

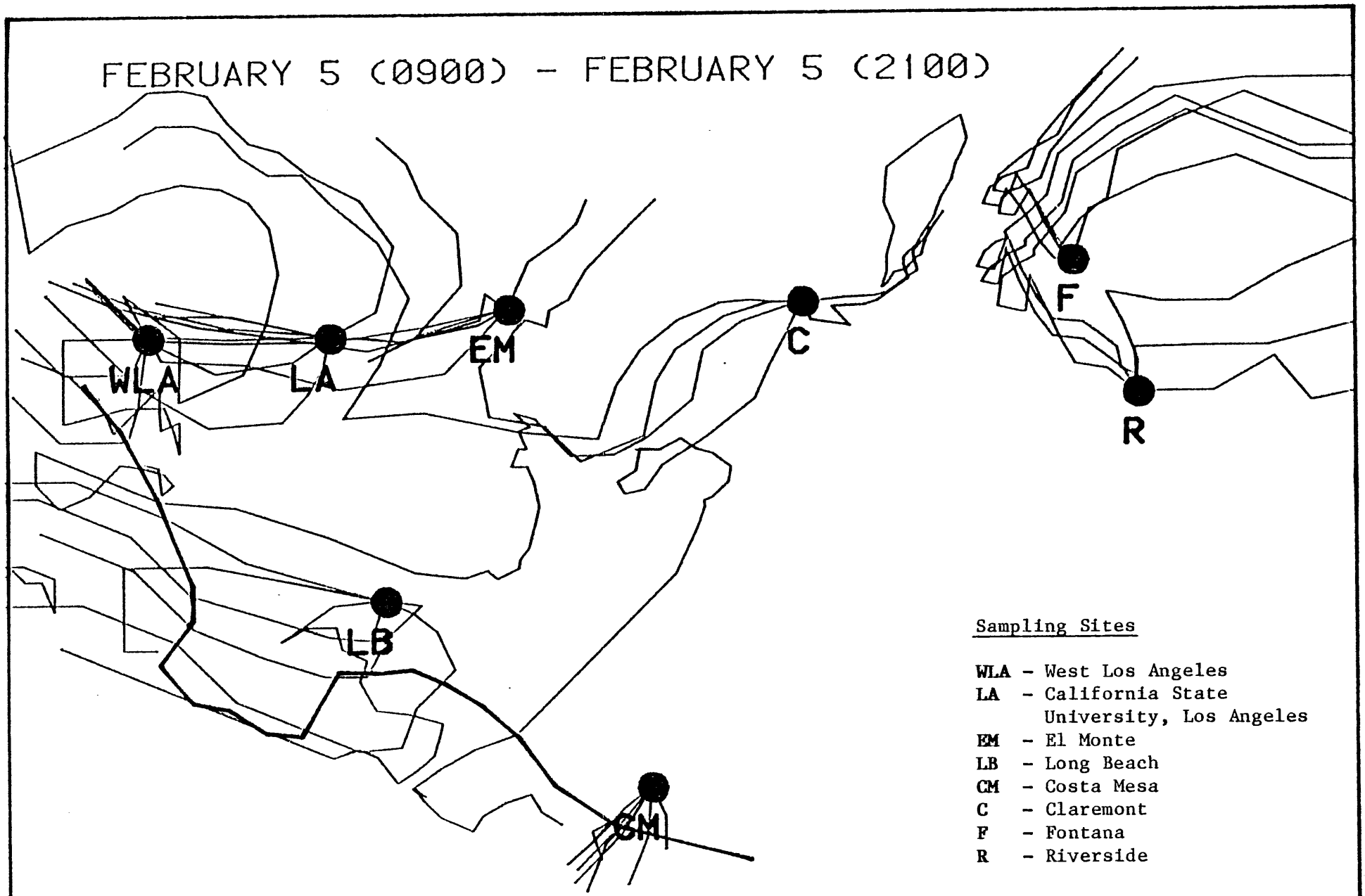

Figure 10. Air mass trajectories for the 12-hour sampling period February 5 (0900) - February 5 (2100) [5D], 1980.

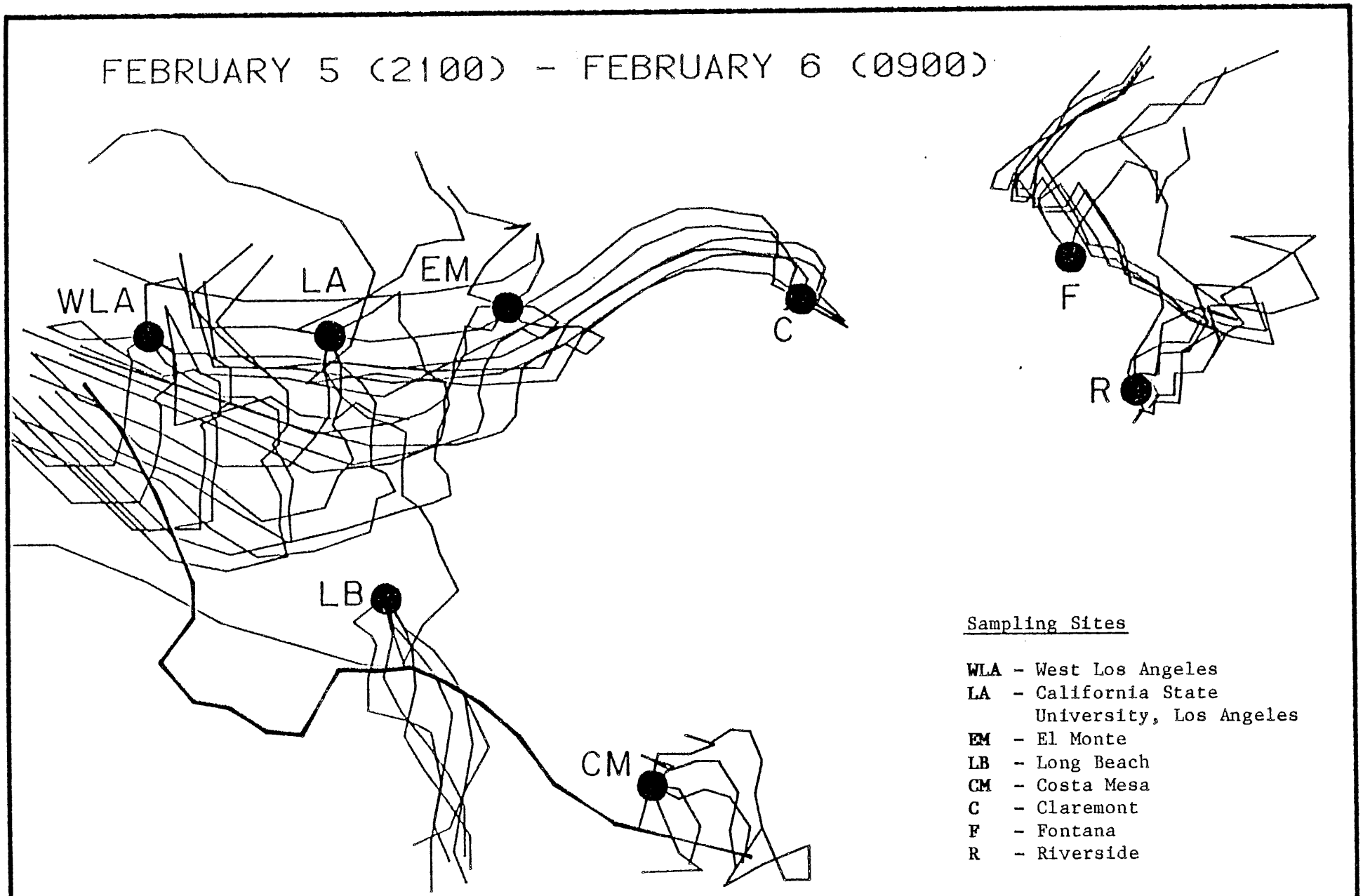

Figure 11. Air mass trajectories for the 12-hour sampling period February 5 (2100) - February 6 (0900) [5N], 1980.

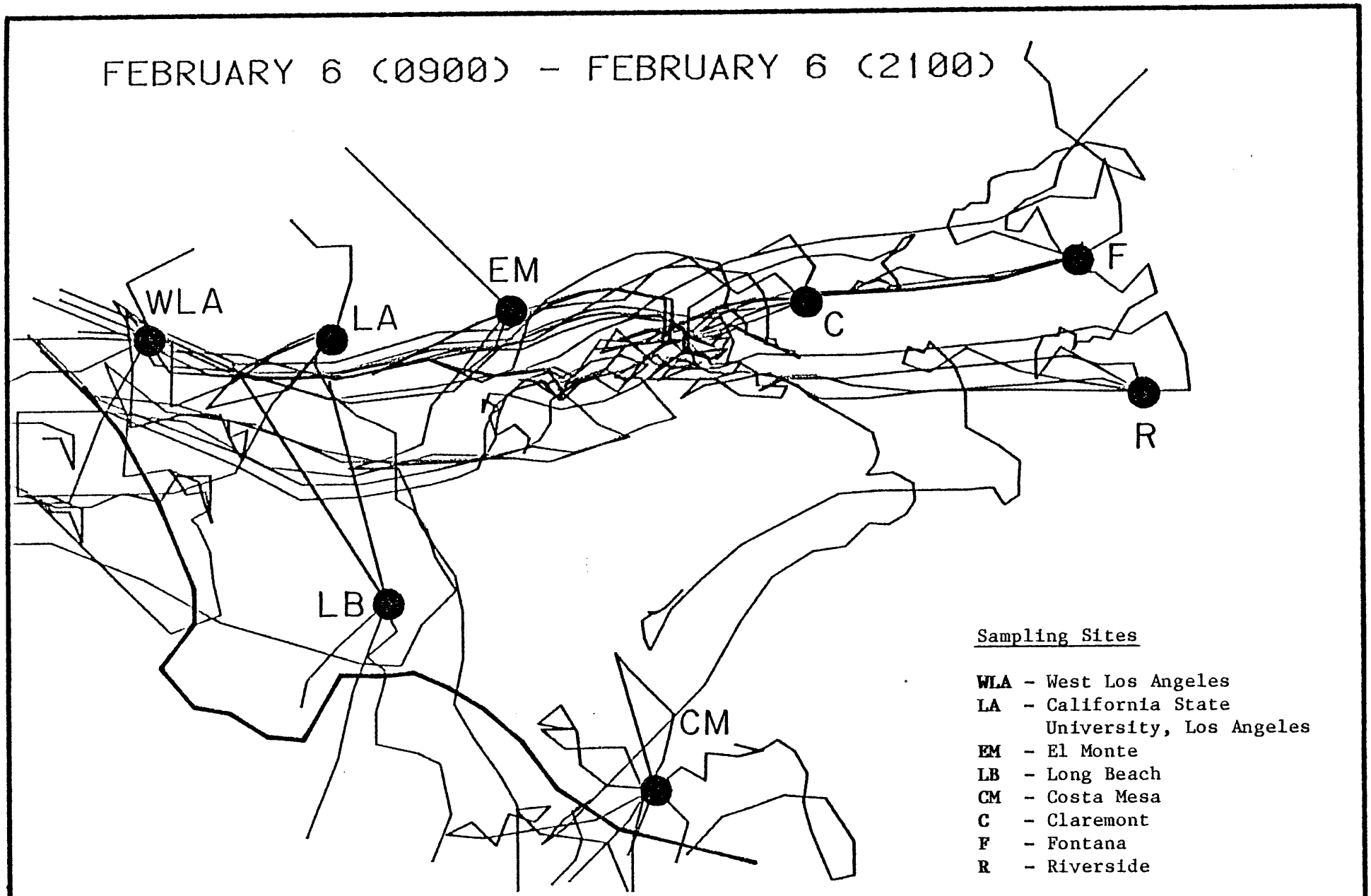

Figure 12. Air mass trajectories for the 12-hour sampling period February 6 (0900) - February 6 (2100) [6D], 1980.

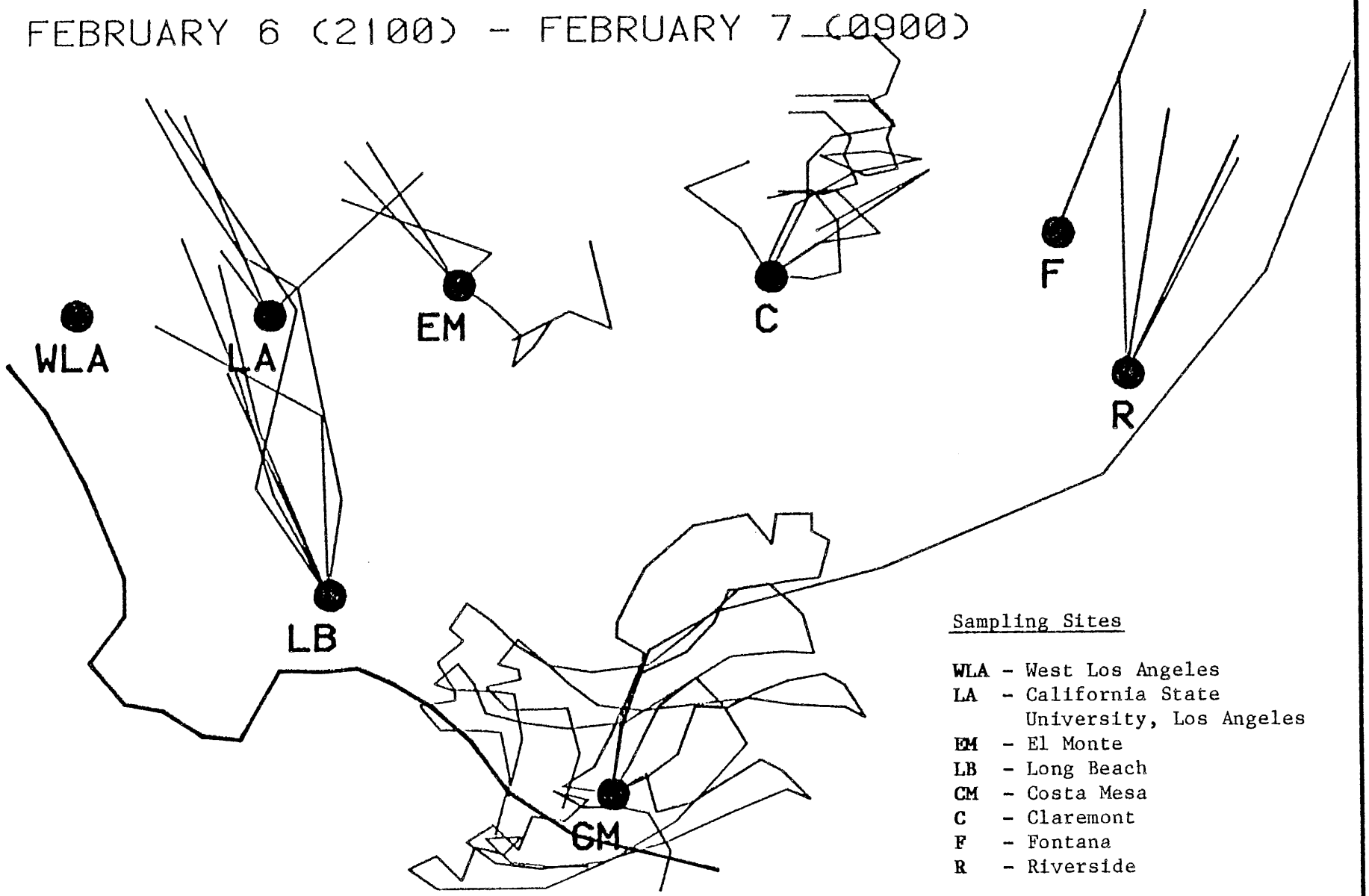

Figure 13. Air mass trajectories for the 12-hour sampling period February 6 (2100) - February 7 (0900) [6N], 1980.

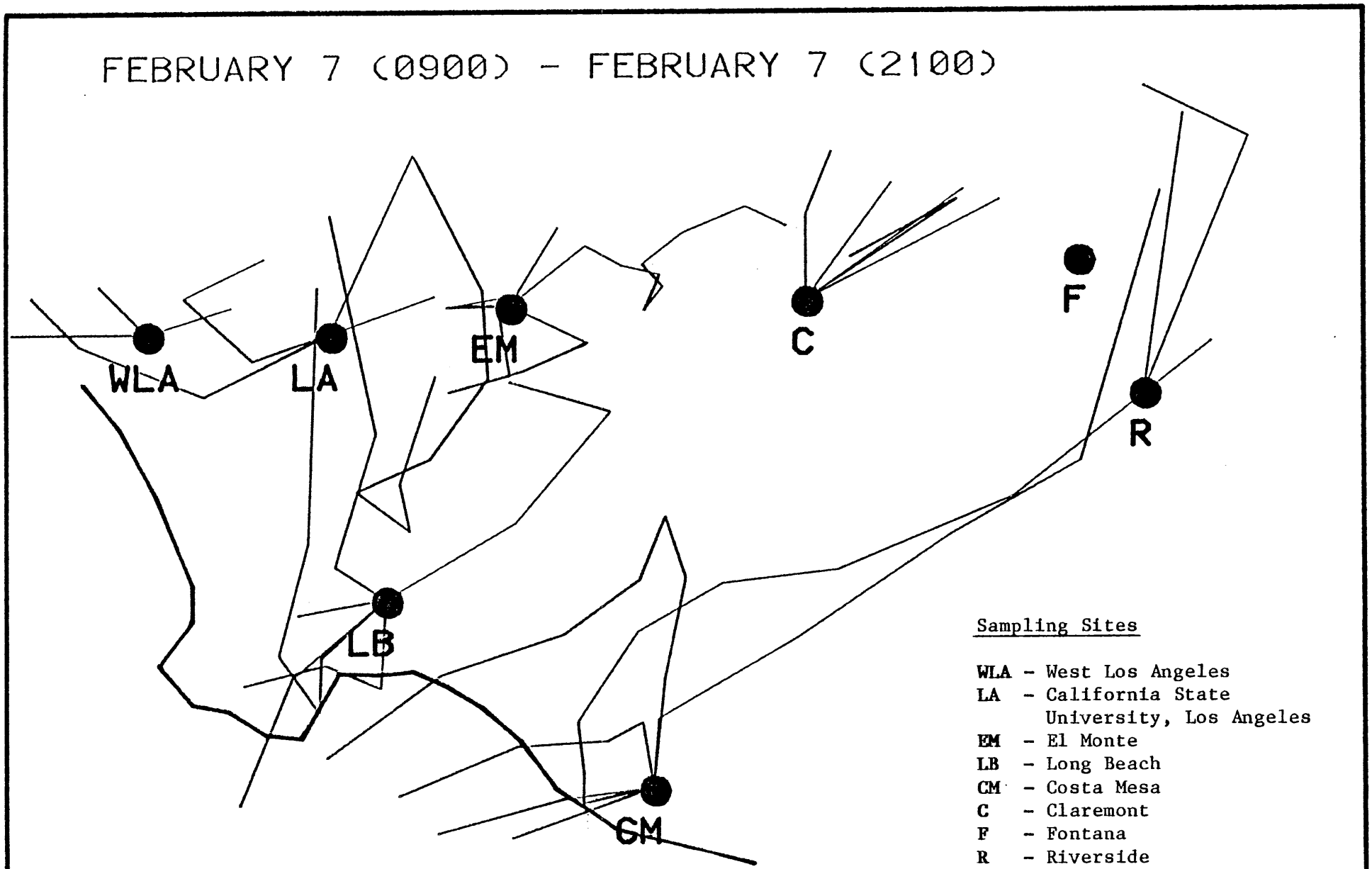

Figure 14. Air mass trajectories for the 12-hour sampling period February 7 (0900) - February 7 (2100) [7D], 1980.

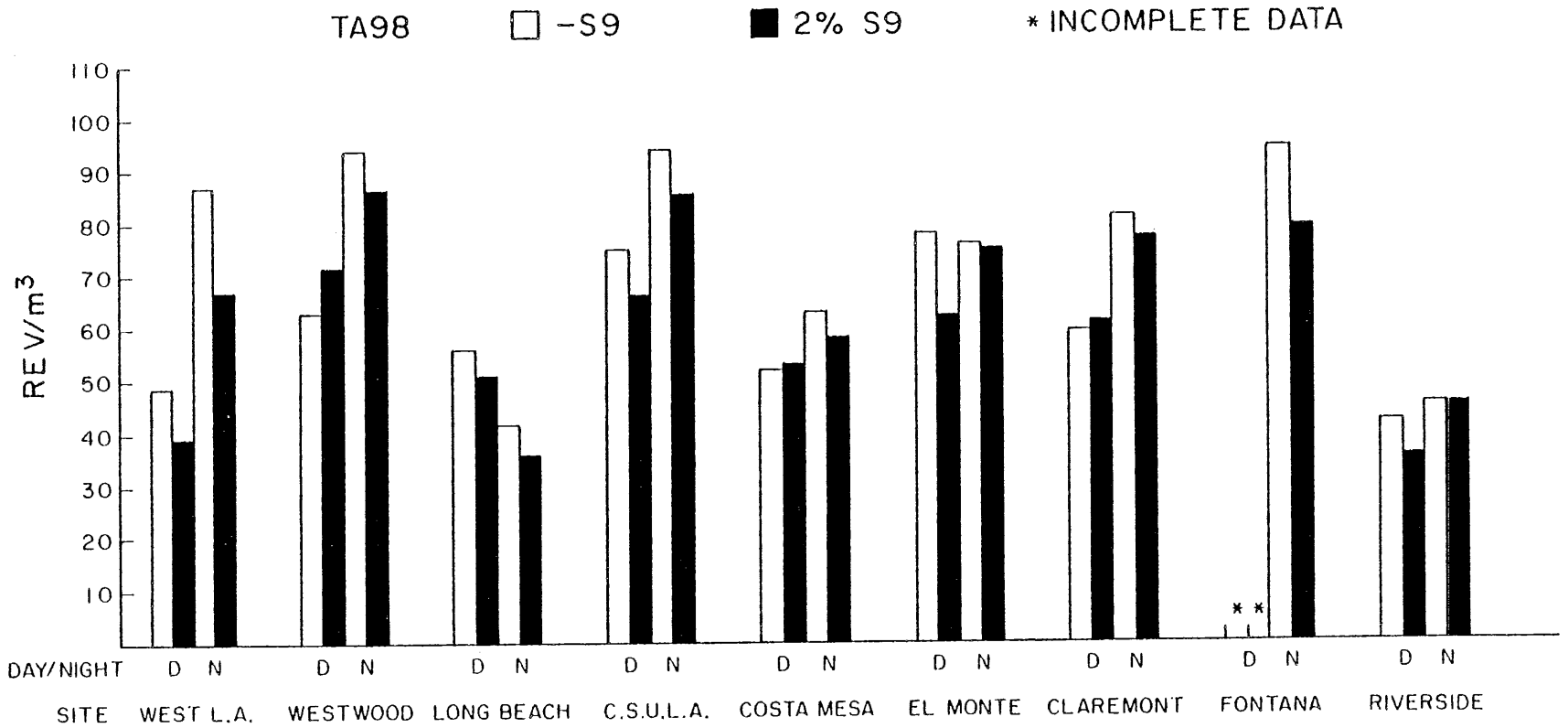

Figure 15. Mean airborne particulate mutagen density (revertants/m^3 ambient air) using strain TA98 of total extracts of samples collected at nine sites throughout the South Coast Air Basin, February 4-7, 1980.

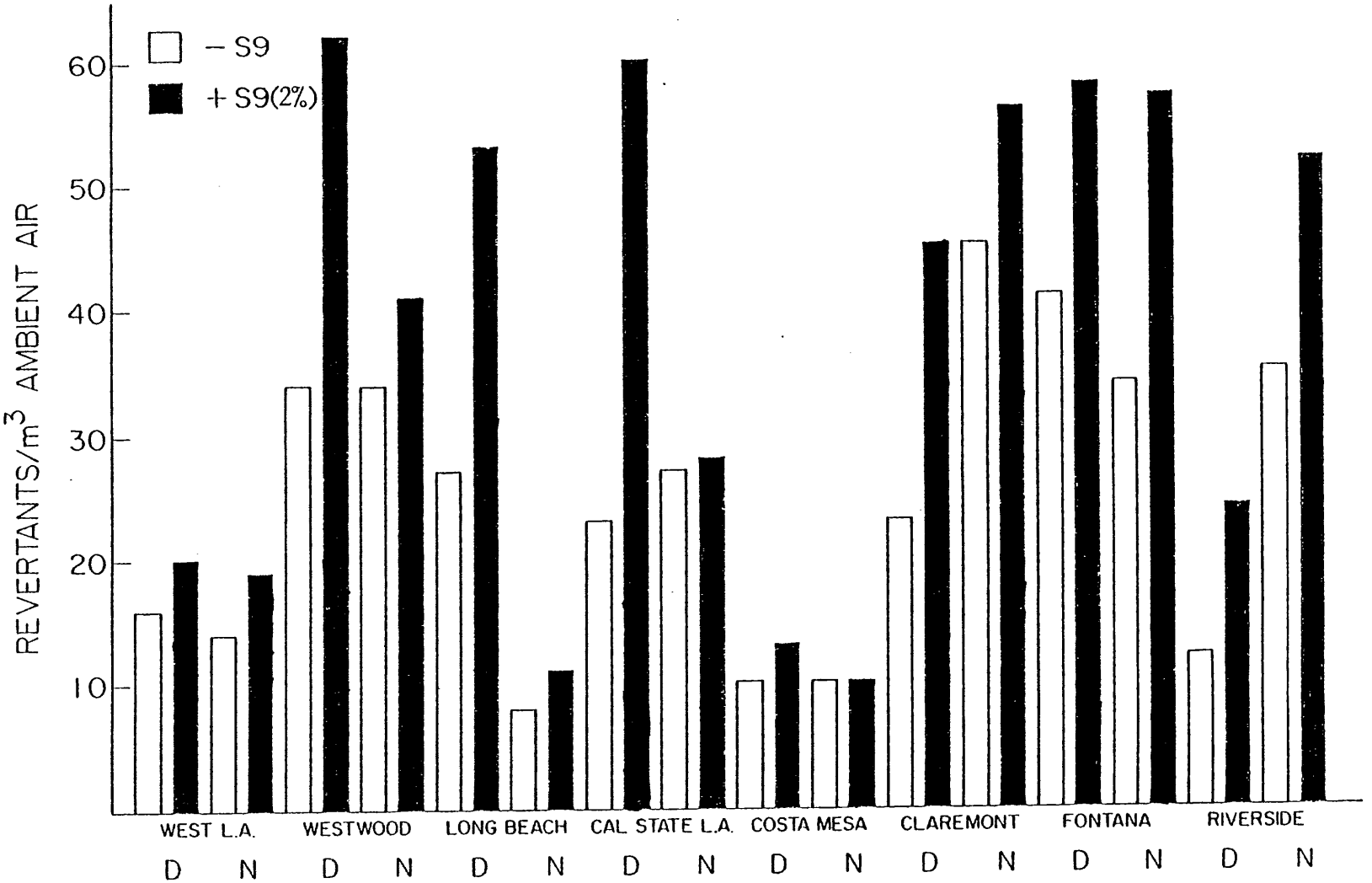

Figure 16. Airborne particulate mutagen density (revertants/m^3 ambient air) using strain TA98 of total extracts of samples collected at eight sites throughout the South Coast Air Basin, July 11-14, 1979.

collection, probably due to the variability of wind direction and speed during the sampling period (see next section). Thus, the three-day average values presented in Figure 15 are not interpretable in terms of transport phenomena.

Figures 17 and 18 show the measured 12-hour average values of direct-acting mutagen density (revertants/cubic meter) and mutagen loading (revertants/μg particulate), respectively, during each of the six 12-hour sampling periods at the nine sampling stations, as determined by our procedure with TA98. The advantages of the improved precision which we have attained in this study are readily apparent. It is clear that sampling was initiated during a period of high particulate mutagenicity and that the measured activity declined during the sampling period as the air quality improved. The peak 12-hour average levels measured here exceeded the 36-hour average levels by more than 100% at several sites. The distribution and intensity of particulate mutagenicity over this period is consistent with the other measured pollutant data and the calculated wind trajectories.

The sampling period started at 9 p.m. (2100 hours) on February 4, 1980 when relatively high levels of ozone for this season were predicted. Indeed, on February 6 ambient air quality data taken at the ARB Mobile Laboratory at the UCR campus showed an ozone peak of 110 ppb accompanied by clear sunshine, mild temperatures (26°C max) and moderate humidity (40% min). The morning NO_x peak of 190 ppb is indicative of substantial levels of primary pollutants, while the PAN maximum of 13 ppb is typical of "winter smog" episodes.

A number of observations can be made from the air quality data. First, the particulate and gas phase data both show a sharp reduction in pollutant concentration on February 7 when a Santa Ana wind pattern became established. Second, the particulate loadings and mutagen densities at the freeway downwind site were significantly greater during the daytime when westerly winds predominated, but lower at night when air flow was light and variable. Higher total suspended particles (TSP's) were also observed during the day for this pair of sites as well as most of the others. As expected, inland receptor areas showed higher aerosol concentrations than the coastal sites.

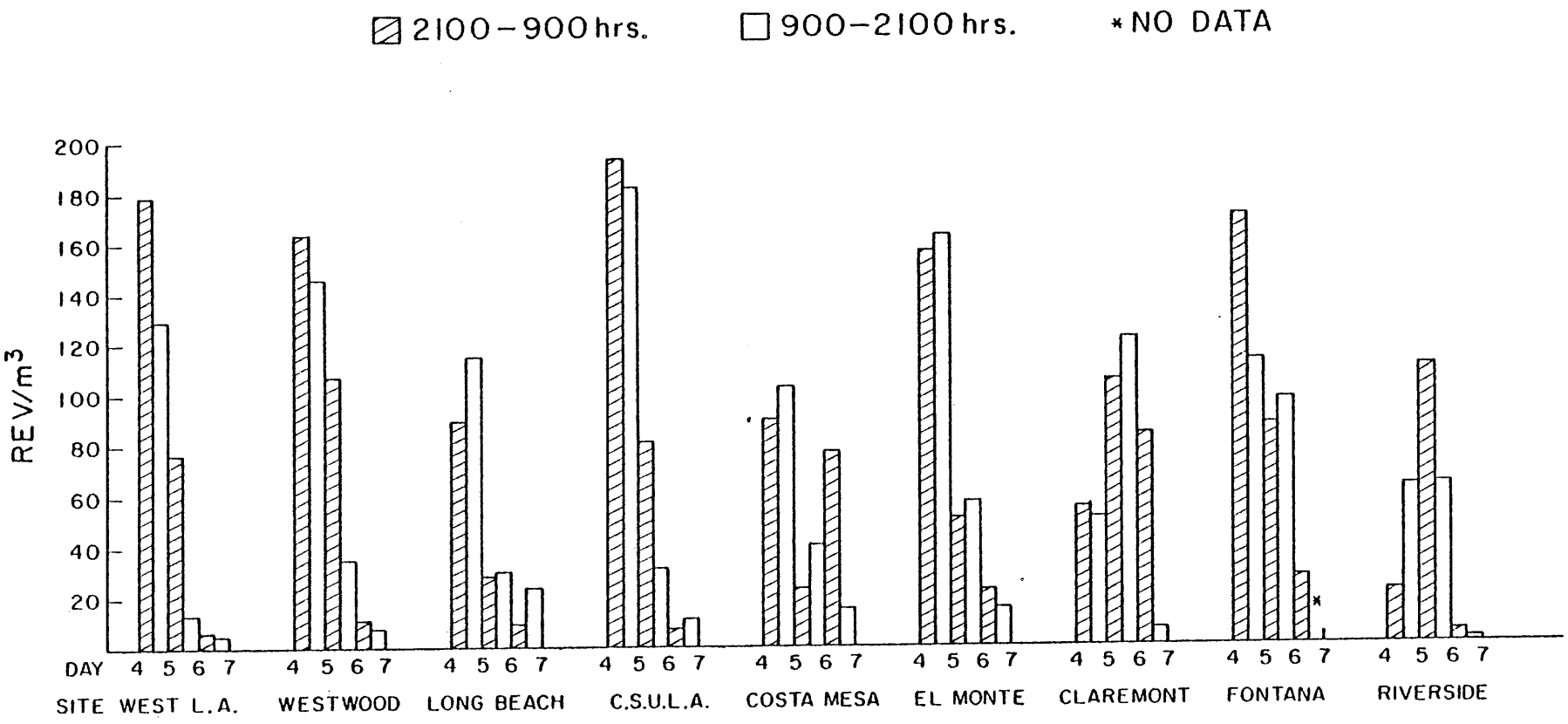

Figure 17. Direct acting mutagen density (revertants/m^3 ambient air) using strain TA98 for total extracts of particulate samples collected using 12-hour periods at nine sites throughout the SCAB, February 4-7, 1980.

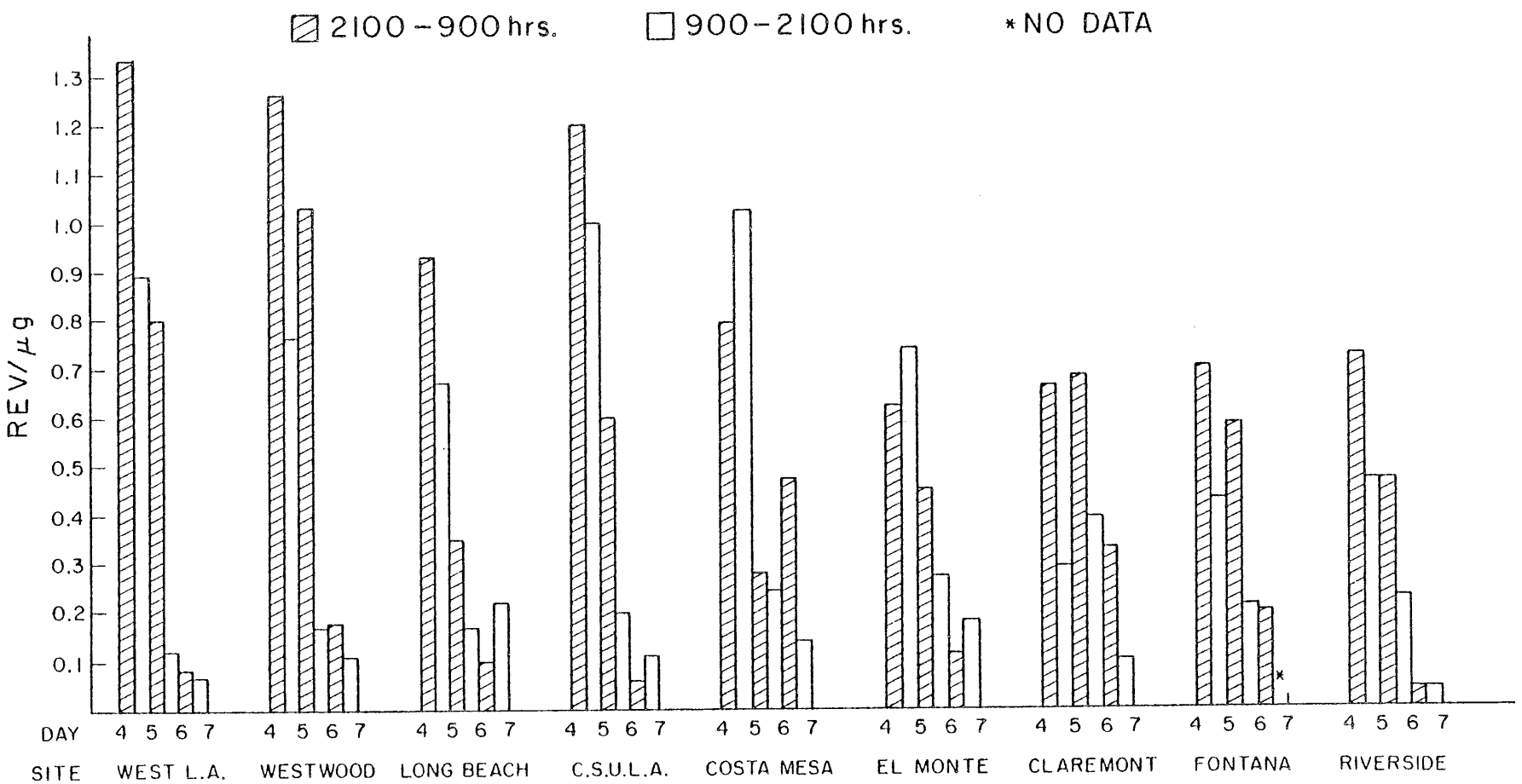

Figure 18. Direct activity mutagen loading (revertants/µg particulate) using strain TA98 for total extracts of particulate samples collected using 12-hour periods at nine sites throughout the SCAB, February 4-7, 1980.

The trajectory calculations show that offshore flow prevailed at the inland sites during the first sampling period, when the highest mutagen density and loading occurred at the coastal and intermediate sites. Onshore flow beginning on the afternoon of February 5 produced transport to the inland sites and resulted in a reversal of the prior distribution. Finally, strong winds which began on the evening of February 6 resulted in lowered values of the mutagenicity and other pollutant levels excepting the TSP values, which more probably raised as a result of dust resuspension by the winds.